PRE-PRODUCTION CHECKLIST
and
MANAGEMENT TOOLS
for
GREENHOUSE VEGETABLE AND FLOWER GROWERS

Farmer to Farmer Program – Kenya

First Choice Seed Enterprises Ltd,
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KENYA GREENHOUSE VEGETABLE AND FLOWER PRODUCTION:

INTRODUCTION:

Of the many production problems encountered in the greenhouse industry, the most important are directly related to POOR VENTILATION AND THE EXCESS HEAT DEVELOPED LEADS TO THE FOLLOWING:

- REDUCED PHOTOSYNTHESIS
- POOR POLLINATION
- EXCESS HUMIDITY, WHICH LEADS TO
- HIGH INCIDENCE OF FOLIAR DISEASE
- OVER WATERING, WHICH LEADS TO
- LOW ROOT OXYGEN SUPPLY
- SLOW GROWTH
- AND A HIGH INCIDENCE OF ROOT DISEASE, BLOSSOM END ROT

and ultimately low yields and frustrated growers. Each of these factors will be discussed in relation to many other factors that lead to success or failure.

Although excess heat seems to be indigenous to Kenya, once a greenhouse is constructed, the problem is intensified. The growth of a plant is directly related to temperature. The hotter it is the faster they grow. However, photosynthesis, the process used to trap sun energy and turn it into sugar slows around 28-30C and may eventually stop around 35C. We often see greenhouses running well over 35C.

When this occurs, photosynthesis stops but plant growth continues to increase at the expense of sugars made when the plant was cooler. In short, when these high temperatures exist the grower is actually making the plant grow faster than it is capable and at the same time causing the plant to use up previously stored energy. If this continues for several days the plants become weaker, stems elongate, fruit growth is slow, poor taste, poor quality, and flower color is a result. This is often accompanied by flower and fruit abortion. Like a person who is forced to run faster than they are capable, eventually they collapse.

In the case of the tomato, pollination of the flowers is needed to start the development of fruit. When the humidity is very high, pollen tends to stick together and only a little pollination occurs…thus either few fruits develop or they may mature very small.

Next, hot air contains far more water than cool air. Measurement of this water content is called relative humidity (RH). When the greenhouse cools in the evening, the air cannot hold as much water and it condenses on everything present (leaves, fruits, etc.)

Spores of diseases such as bacteria and fungi are like tiny seeds. Many float around in the air whereas others are transferred from place to place by feet, hands and tools. In order to germinate and attack a plant leaf or fruit, they must have a particular temperature range, a film of water, and time. This time requirement is usually only 4-6 hours depending on the disease and temperature required. In short, as the temperatures cool in the evening, water condenses on the leaves and leaves are wet for many hours. If spores are present these diseases will have penetrated the plants by morning.

Growers often apply excess water during times of excessive temperature. Soils in this area of Kenya are very fine textured and can contain much water at the expense of soil oxygen. Low oxygen rates result in slow grow blossom end rot and high incidence of diseases such as bacterial stem rot, phytophthora, pythium and other related organisms.

All of these points will be discussed in more detail later but EXCESS HEAT is the primary reason for poor crop yield, quality and ultimately business failure. For this reason all aspects of greenhouse management, construction, production and later marketing must begin with a broad discussion of EXCESS HEAT.

A secondary issue often arises, that being research data and promotional literature. Take care in reading and believing everything you read. For example, research data developed in Western Europe or the United States can be misleading because of the great differences in climate and latitude. In addition, media that is supported by advertising often blow items such as expected yield information totally out of proportion. Try to get this information directly from growers in your immediate area, not promoters!

Eighteen APPENDICES and several pictures have been added to give fuller information regarding many of the issues described through this manual.

PLANT GROWTH AND DEVELOPMENT:

We begin by looking at what makes a plant grow. Just as a photocell in a hand held calculator changes energy from sun light into electricity, the green plant leaf changes this energy first into a sugar.

Photosynthesis: Plants trap energy from the sun or other intense illumination sources and combine this energy with carbon dioxide (CO2) and water (H2O). This energy is then in a chemical form that we call sugar and can be used immediately or stored away for later use. This process is called photosynthesis.

There are many different carbon compounds called sugars. Each has its own name such as glucose, sucrose, fructose etc. The characteristic they all have in common is that they are made up of carbon (C), oxygen (O), and hydrogen (H) and contain a great deal of stored energy. These sugars are then used by plants in the production of stems, leaves, roots, flowers, seeds, fruits and storage organs.

The initial energy product, sugar, is often converted to other energy forms prior to use or storage. For example, potatoes store energy as starch, other plants store energy as fats, oils, proteins, etc.

Generally speaking, the higher the intensity of the light the better or until the plant becomes too hot. In many plants photosynthesis begins to shut down around 32C and often stops only a few degrees higher. In short, a sunny day may seem to be very productive in terms of trapping light energy but if the plant gets too hot this process stops.

If the plant is capable of trapping only a small amount of energy, this energy will go towards the development of leaves, stems and roots before being stored. If additional energy is available, flowers, seeds and fruit will develop and if even more energy is available it will be stored for later use. As an example, a potato plant grown under low light conditions may appear healthy, have flowers and small fruits. However if the energy level is too low, no storage is capable and either no potatoes will develop underground or they will be very small. In short, the potato is a storage organ and develops only after all of the other plant needs are supplied. This order of energy use can also be seen in animals.

Light: Light from the sun contains many individual colors but only the blue and red portions generally are used in photosynthesis. Light, like water, can be described in both quantity (how fast water flows) and duration, (how long water flows). Light, direct from the sun has the greatest energy level whereas "sky light", that coming from other than directly from the sun has a very low energy level. For this reason, greenhouses are seldom put up near large trees.

Temperature: The speed or rate of growth in plants is controlled by temperature. As temperatures rise, the speed of chemical reactions that leads to growth, increase. In short, a grower can speed up or slow down the growth of any crop by merely altering the temperature. Mammals on the other hand maintain a constant body temperature. During periods of dark cloudy weather, temperatures are generally lowered. If temperatures are not lowered, the plant may be forced to grow faster than it is capable or grow faster than the available energy supply (light) will allow. When this occurs there is insufficient energy and storage stops, new flowers and small fruit may abort and plants go into a "maintenance" mode. Cucumbers are very sensitive and will often begin to abort new flowers when periods (several days) of dark cloudy weather occurs and temperatures are not lowered.

Carbon Dioxide (CO2): CO2 is used in the energy trapping system or sugar making process. Since it is found in very low levels in the environment, increasing the CO2 level in the air around the plant will actually speed up growth by making the photosynthetic process more efficient. CO2 in the atmosphere is somewhere around 300-350 parts per million (ppm) or milligrams/liter (mg/l) of air. This level can be raised to 1000-1500 ppm and growth will increase substantially. Adding CO2 during winter's low-light periods is particularly effective in far northern and southern latitudes. Because gases diffuse very rapidly, greenhouse ventilators are usually kept closed or open only slightly when CO2 is being increased as it will quickly diffuse out through open ventilators.

Conversely, plants in tightly closed greenhouses where no additional CO_2 is added, quickly remove most of the available CO_2 and photosynthesis stops. Since photosynthesis does not occur during dark periods, adding CO_2 at night has no benefit. This process will seldom be observed in Kenya but growers should be aware that it is possible. Where greenhouse soils contain large amounts of organic matter, substantial amounts of CO_2 are given off daily as decomposition occurs.

Plant Nutrients: Plant nutrients, although referred to as Plant Food by the world, are not "foods" in the usual sense of the word. To the plant and animal, foods release energy when consumed by them. Plants and animals both need Nitrogen, Phosphorous, Potassium and other elements but these are not "energy products"! Plant food is "light" - this is the primary source of energy for all green plants. If all nutrients and water are available in their optimum amounts, further additions do nothing to increase photosynthesis. Increasing Nitrogen, on the other hand, does have the ability to generally speed up or direct energy products into vegetative growth as opposed to reproductive growth (flowers, seeds and fruit). It appears to greatly promote the production of leaves, stems and roots at the expense of other uses. For this reason, excessive Nitrogen fertilization often does more damage than good where flowers, seeds, fruit or storage organs are the primary intent of production.

Soil Oxygen: Every rapidly growing plant part requires oxygen. Root tips are no different from stem tips, newly developing leaves and fruit. They need oxygen and soil compaction and excess irrigation greatly reduce movement of oxygen, CO_2 and other gasses into and out of the soil. Every effort must be made to maintain the soil in a very loose well drained condition. More will be said regarding this under Soil Amendments, Irrigation and Blossom End Rot.

Greenhouse Production: Published greenhouse production schedules assume that particular light levels and temperatures are occurring. This is why production schedules usually differ from summer to winter as well as day vs. night. In the case of tomato or cucumber production, schedules are designed to push the plant into maximum fruit production. This means that any major reduction in energy supply (light) must also be accompanied by a reduction in greenhouse temperature. If this is not done during periods of cloudy weather, flowers and small fruit may abort. In short, with reduced energy levels and high temperatures, the plants are being forced to use every bit of available energy in growth. When any of these critical growth factors are changed, flower production, pollen development, fruit development and energy storage are all impacted.

Quality: As consumers of plant products we often speak of "quality". In essentially every case "plant quality" can be traced back to a plant capturing and storing far more energy from the sun than it needs to grow. For example, the best tasting vegetables and fruits will have much higher sugar content than those with poor taste. Flowers from plants with high levels of stored energy will be brighter, more intense have greater stem strength and a longer vase life (shelf life) etc.

In every case the primary goal of the grower is to produce not only the greatest kilograms of products, greatest number of flowering stems, etc. but also the highest "quality" products as these will bring the greatest consumer acceptance and highest market price.

The Concept of Source and Sink: When discussing products such as sugars in the plant system one needs to keep in mind that these materials move from areas where they are being made **(source)**, to areas of immediate use or storage **(sinks)**. The leaf is usually thought of as the primary **source.** Growing points (stems and roots), newly expanding leaves, flowers, seeds, fruits and storage organs such as bulbs, tuberous roots, etc. are the primary **sinks.**

It is interesting that there is a hierarchy in the plant regarding priority of or strength of **sinks.** For example, maintenance of the plant generally comes first, that is, growth of leaves, stems and roots. Second in line is the growth of new flowers, seeds and fruit. The filling of storage organs (tubers, fleshy roots) normally comes last. However, in many plants, as in animals, the growth of seeds and fruits (babies) become extremely strong sinks particularly as their size and maturity increases. They seem to be able to pull the last bit of energy from the plant which may cause yellowing of foliage and nearly total collapse. If there is a shortage of energy products, the filling of storage organs is usually the first to be reduced.

We've all seen plants that look like they are dieing but flower and seed development is continuing. This concept of source and sink is often seen particularly in crops like cucumbers where with low energy values, new flowers and tiny fruit abort but existing larger fruit continue to develop at the expense of the parent plant.

GREENHOUSE CONSTRUCTION AND MAINTENANCE:

There are several major problems dealing with the physical facilities that all greenhouse producers face. These problems must be addressed prior to construction or they will continually promote difficulties in every crop.

Site Planning: In far northern and southern latitudes greenhouse orientation is very critical and is determined by the amount of sunlight available during the winter months when days are often cloudy and short. In these areas greenhouses are normally oriented East to West in order to take advantage of maximum winter sun light. In Kenya, however, orientation is most critically viewed in relation to wind direction since **excess heat is the major problem.**

When using small greenhouses with low sides (eaves) it is suggested to align the greenhouse so that the primary air movement comes in the end of the building. For greenhouses with high sides (2+ meters) and roof ventilators, ventilators should be open on the lea side of the house (away from the wind). In addition, sides and ends should be capable of being opened

If at all possible, all building must have roof ventilators and low side ventilators. This causes a chimney effect where cool air enters the bottom and hot air exits out the roof. Where buildings are made without these vents, hot air is trapped inside further making the problems of excess even worse.

If wind movement is normally very slow or quiet, it is suggested not to use "ridge and furrow" (several gutter connected buildings) buildings but to use free standing units. This will increase cost due to the added sides but will usually allow adequate cooling during low wind speeds and calm periods.

Trees close to the greenhouse site can be an advantage if wind speeds are often very high. On the other hand, trees may cause excessive shading and be a source of insects particularly if the trees are up-wind from the buildings.

When siteing a greenhouse, the ultimate goal is to reduce temperature and relative humidity!

Greenhouse Types (Don't bet the farm): There are many greenhouse types and shapes used throughout the world. When beginning a greenhouse business, choose a low cost building. Always select one with a simple wood, pipe or steel tube frame. Learn to raise crops before laying out large amounts of money for more sophisticated buildings. More expensive, permanent structures can always be purchased after you've proven that you can grow crops and make a good profit. Do not purchase a building constructed of PVC plastic pipe. Light penetrates PVC and the plastic becomes brittle and will break in a few years.

Buildings with a rounded ridge such as a Gable or Quonset shape are suggested because the plastic covering can be pulled down tightly on the frame thus reducing wind damage (see later). PICTURE Buildings with continuous or intermittent roof vents, as well as those mentioned above may be fitted with narrow fabric belting or ropes placed over the top of the roof from eave to eave and spaced between the individual rafters. These will help prevent excess movement due to wind.

As mentioned earlier buildings often overheat thus shutting down photosynthesis. For this reason buildings should be constructed so that ends, sides and roof ventilators can be opened. Side plastic is often anchored at the eave and taped to a horizontal pipe (such as ¾ inch PVC) at the ground. A "crank" handle is then added to one end of the pipe and the entire side can then be rolled up to any height. Small vertical barriers are added next to the walls in order to prevent violent swinging due to wind.

Common Greenhouse Covers: There are three things that can greatly reduce the longevity of polyethylene greenhouse covers, i.e. wind, ultra-violet light (u.v), and heat.

When initially designing a greenhouse, check the sizes of polyethylene available and design accordingly. Always make the building about 1.5-2 meters shorter, and 0.5 to 1 m narrower than available materials. Once the building is constructed, the only major future cost is the plastic replacement. By making the building fit the cover, almost nothing is wasted.

Greenhouse Grade Polyethylene: Several different formulations of polyethylene containing an ultraviolet inhibitor (uv) are available. Some companies produce covers that contain other chemical conditioners, imbedded plastic mesh, several layers of film all attached together or contain a plastic screen for greater strength. Generally speaking, always look for a product that is guaranteed for 3-4 or more years. Polyethylene usually comes in .004, .006 and .008 inches (mil) thickness. Heavier materials, of course, are used in areas of excessively high wind speeds. Construction grade polyethylene does not contain any u.v. inhibitors and usually lasts for only 2-3 months. Construction grade materials are sometimes used for greenhouse sides but must be replaced frequently. If used, use only where they will receive NO direct sunlight (north sides or ends).

Wind Problems: Large trees located close to buildings may cause unnecessary shading (light energy reduction), reduce much needed air movement and contribute large numbers of insects that are blown out during periods of high winds. On the other hand, they may have a positive effect by reducing high wind velocity.

Wind causes unnecessary movement which can, in time cause breakage of the plastic. This can be reduced, as mentioned above, by selecting a structure that has a rounded roof. This allows attachment of ropes or straps to help hold the plastic closer to the frame. PICTURE

Heat Associated Problems: When sunlight penetrates plastic and strikes a dark surface, much of the light is changed from the various colors (collectively white) to infra-red or heat energy. Where the surface is light colored or white, the light is most often reflected back out and does not create heat.

When greenhouse covers are applied to frames of dark or weathered wood, black pipe or rusted metal excessive heating can cause deterioration at the places where the plastic is in continuous contact with the hot building member. All dark framework that is exposed to "direct sun" must be painted with white latex paint. Painting will greatly reduce or eliminate this problem. Do not use an "oil base paint"….use only latex paints that can be diluted and cleaned with water.

A second but similar method is done by applying a narrow strip of white paint or whitewash directly to the outside of the polyethylene immediately above any structural members that come in contact with the plastic. Thus the sunlight is reflected prior to entering the plastic. In all cases don't be concerned unless the structural member receives "direct" sunshine and can become very hot to the touch.

Low Roof Angles: Greenhouse polyethylene on a very low angle roof will often begin to collect water and sag during a heavy rain. For this reason, it is sometimes necessary to add additional support under the polyethylene and near the eaves. The polyethylene will seldom brake before the structure breaks from the weight of the collected water.

Excess Ground Water: Greenhouses also shed a great deal of water during rain storms and this water must be channeled away from the building as quickly as possible. If this is not done, much water will enter the building from below the soil surface. Soil saturation and accompanying problems then occur, i.e. root disease, low oxygen, poor root grown, blossom end rot, etc. In addition to these necessary ditches, ditches should be placed on the up-hill side of the greenhouse in order to catch rain that may move on the soil surface. The grower needs to maintain full control of soil bed moisture. Without these measures, they lose control.

Role of the Grower: Successful growers always try to reduce greenhouse temperature when light energy is reduced….in other words, try to balance the energy being accumulated with what is being used. Try to promote maximum photosynthesis. This is done by ventilating the greenhouse before excessive temperature shuts down this process. Extended periods of hot, cloudy weather greatly reduces photosynthesis yet promotes rapid growth. Under these conditions, cucumbers will often begin aborting flowers in only a few days.

High plant "quality" in every case is directly related to the amount of energy that is trapped and held in storage, i.e. flower color, fruit flavor, sweet taste, storage organ size as in potato, etc. And in each case, control of greenhouse temperature is absolutely essential.

THE GREENHOUSE TOMATO:

Tomato Types: Tomatoes come from Central and Northern South America. They are perennials and will live for many years if handled properly. They come in many colors, i.e. red, orange, yellow, purple, green, black and mixtures. Flavors vary considerably and there are hundreds of varieties on the world market. Tomatoes come in many sizes from 2 to 20 cm in diameter. Varieties listed as "heritage" usually are those that can be traced back many years and may be very similar to what our parents grew.

F1 Hybrid varieties are produced from very specific parent plants (hand made crosses) thus giving extremely uniform plants and fruits with each years planting. Inbred varieties are allowed to grow in large populations of a single variety and intercross freely from one plant to another. Plants from inbred varieties are generally not as uniform but normally produce a very acceptable plant and yield. Inbred types are used almost exclusively for field culture. The greenhouse tomato grower must always strive for the highest production and quality and should therefore always use F1 hybrid varieties specifically developed for greenhouse production.

Over and above all these characteristics tomatoes are classified as “determinant” or bush type and “indeterminant” or vine type. Greenhouses tomatoes are all of the “indeterminant” form.

The main stem of bush types terminate in a flower cluster. New growth results from side shoots starting further down the stem thus causing the “bush” effect. Vine types, however, maintain normal leaves at the end of the stem with flower clusters coming off the stem as “side branches” thus forming a vine type of growth.

Growth Factors:

Germination: Tomato seed is usually germinated around 23-25 C.

Production Temperatures: Tomatoes generally prefer day temperatures from 20-25C and nights of 15-18 C. Temperatures above 27C should be avoided since photosynthesis will begin to shut down and probably totally stop by 35C.

Soil Oxygen: As with most plants, soil oxygen is very important. Any plant part that is actively growing requires large amounts of oxygen, i.e. root tips, storage organs such as potatoes, etc. Soil media should never be compacted around roots when planting and all soil activity should promote loose well drained conditions. Once a plant bed is thoroughly tilled no one should step in the beds. When planting, set seedling into holes and merely refill the hole with loose material….never pack them! The first irrigation is usually done with a watering can which has “small” holes in the sprinkler tip. When initially watered, the soil will settle around the roots and make a good root/soil connection. If a watering can has large holes in the sprinkler tip, excessive compaction of the soil will occur. One of the primary reasons for adding large quantities of organic materials is to physically open the soil, increase water drainage and soil oxygen. Maintaining adequate soil oxygen is a production factor of highest concern.

Planting and Spacing: Plants are usually set in a double row. These can be set adjacent to each other or in a “staggered” arrangement. Since there is usually no root competition for water or nutrients, care should be taken that the tops do not compete for light….the primary energy source. Spacing between plants in the row may vary from 25 to 40 cm depending on variety (some have larger leaves than others), climate, and many other factors. Roughly 2.3 plants per square meter is often used. It is suggested that new growers begin using a wider spacing than initially suggested by suppliers (35-40 cm as opposed to 25cm). Plants are often grown as a single stem throughout their total growth cycle. However, many growers pinch the crop shortly after starting and train it so as to have two main stems. The new grower has much to learn. In short, don’t try to extract every bit of production by planting too close together. Give yourself time to learn what appears best under your conditions.

Interior Layout of Planting Beds: The vast majority of growers use buildings with side and roof ventilators. They also plant crops like tomatoes and cucumbers lengthwise of the building or parallel to the side ventilators. When crops reach 1.5 m or more, most of the ventilation coming in the side vents is cut off, cool air is force straight up and crops quickly overheat. Essentially, no cool air ever makes it to the center of the house. If growers would orient the plant rows across the house or perpendicular to the side vents, air could come in the vents, move down the rows and between the plants prior to moving up and out the roof. This seems like a very simple move but cooling would be improved a thousand percent.

Plant Support System: Generally, the plant support system is totally separate from the greenhouse structure. Two to 2.5 meter vertical posts (above the soil) are set in the plant beds at various intervals (3-4 meter) depending on their construction. Heavy wires are run lengthwise and heavy plastic twine tied loosely at the base of each plant is extended up to the wire and tied with a slip-knot. Small sized "barbed wire" often works well in this situation in that it doesn't tend to stretch like many other wires and due to the barbs, tied strings/twine cannot slide one way or the other. The twine is usually made long enough to extend to the wire and back again to the soil so as to accommodate lowering the stem as fruiting is completed at the stem base. Heavy wires are often run across the house and tied to the bows (rafters). This merely helps prevent the entire system from falling to one side or the other. Keep in mind that a 2 meter tall plant with many fruit is very heavy and the house will be planted with hundreds.

Setting and Resetting Support Twine: As the plant grows, the twine which is loosely tied at the stem base is wound around the tomato stem for vertical support. When the plant reaches the overhead wire (usually 2 to 2.5 meters), the lowest fruit clusters have usually already been harvested. These lower leaves and cluster stems are removed, the twine is untied from the overhead wire and the entire plant is slowly lowered about 25-30 cm toward the ground. This process is repeated each time the main plant reaches the overhead wire. The old stems may be carefully wound up in a pile or each plant moved sideways 25-30 cm and retied. Which ever way is used, take care not to break these main stems and keep them off of the moist soil if possible. When removing old fruit trusses and leaves allow these newly cut surfaces to dry and heal for a few days prior to lowering the stems. It's the newly cut surfaces that are most susceptible to disease.

General Pruning: As plants grow, small shoots develop in the axils of the leaves (where the leaf and stem join). If allowed to grow, the single stem vine will have multiple stems. These must be removed as soon as possible so as to maintain a single stem. Very small shoots may be bent sideways and will usually snap off easily (3-4 cm in length). If allowed to grow beyond this size, these stems become hard and must be cut with a knife or scissors. Plant viruses are found in the sap or juice of contaminate plants. While cutting these small shoots, the knife blade becomes infected and the grower spreads the virus to the next plant as pruning continues. Growers often use several knives and place them in a cup of 40-50% alcohol or skim milk and change knives with each plant.

FLOWERING, POLLINATION, FRUIT DEVELOPMENT:

The Flower: Each tomato flower contains both sexes. The female portion is a single light colored structure (white or light green) directly in the center of the flower (pistil).

The male portions surrounding the pistil are called anthers and contain yellow pollen. When the flower first opens, the anthers are closed and the pollen remains inside. In a few days the anthers open and the pollen is available to stigma at the top of the pistil to start the formation of seeds.

Pollination: Pollination is the transfer of the pollen from the anthers to the stigmatic surface of the pistil. Once there, the pollen grain germinates much like a seed and a small tube grows down through the female tissue, locates and fertilizes an egg cell. The new seed now begins to develop. One pollen grain is needed for each seed.

Seed and Fruit Development: Upon fertilization of the new seed a hormone is released which causes the flesh of the fruit to begin developing. A plant with a single seed such as a peach needs only one good pollen grain for its development. Maize on the other hand is a multiple flower and at least one pollen grain must grow down each silk" or pistil and will fertilize and develop one seed. Tomatoes may contain one or many seeds. In tomato, if only a few seeds are formed only a little hormone is produced and the fruit will be very small and un-saleable. Therefore maximum pollination is essential! Since much of the free juice in a tomato forms around each developing seed, highly seeded tomatoes are much preferred. As mentioned above, very high humidity causes pollen to stick together and thus pollination of the pistil is inhibited.

Grower Responsibilities: All steps must occur in order for fruit to form and many problems can occur along the way. When grown outside, the humidity is much lower. There are numerous small bees, flies and other bugs not to mention the wind that helps move pollen from the anthers to the pistil. Under greenhouse conditions the humidity is much higher which makes the pollen stick together and pollination is greatly inhibited. The greenhouse has much less air movement and hopefully, few insects. If nothing is done, little natural pollination will occur and few if any salable fruit will develop.

Promote Maximum Ventilation: In this area of Kenya, greenhouses with large ventilators, cool conditions and much natural air flow show excellent natural pollination and fruit development. Conversely, extra hot, humid, greenhouses with small inadequate ventilation systems exhibit smaller fruit and small total yield.

Mechanical Vibrators: Large commercial growers use mechanical vibrators. These are battery or electrically powered vibrators that are used to touch each flower cluster every other day or 2-3 times each week. The vibration very effectively causes spreading of pollen. The units are often quite expensive (around $100). Because of the humidity in the greenhouse, pollination is often carried out around 10am each day. The air is dryer and heat is not excessive. Many other methods have been tried over the years, i.e. shaking of wires and string, using air blowers such as leaf blowers and nothing appears as good except Bumble bees.

Bumble Bees: Some larger commercial growers use bumble bees for pollination. Where honey bees collect nectar, the bumble bee collects pollen. Use of honey bees in greenhouses is a total waste of time. There are companies that raise bumble bees just for this purpose but they are probably not available in Kenya and are also quite expensive. Bumble bees are excellent tomato pollinators in that they not only collect pollen but they also violently shake the tomato flower in the process. They totally ignore greenhouse workers and are never considered a personal threat.

Artificial Hormones: An artificial hormone is often applied to the flower cluster shortly after most of the flowers have opened. This hormone triggers the development of fruit. Whether or not this material is available to growers is not known at this point. Major greenhouse suppliers in Nairobi may be able to obtain this. Here again, the hormone is used to promote fruit development without seeds and results in a fruit with fewer seeds and less juice.

Hand Pollination: In excessively hot and humid situations growers must often resort to playing bee! Using a soft piece of cotton or a small soft children's paint brush, each open flower is lightly touched to help spread pollen. This is most often done at least 4 times a week if the weather is good and flowers are developing rapidly or three times a week when growth is slower. Although this method is very time consuming, it most often produces larger, greater quantities and more appealing fruit. Take care not to injure the stigma as this may result in no fruit or badly misshapen fruit. Only time and experience will tell how many times a flower will require pollinating for an adequate fruit to develop since many factors control how quickly the individual flowers open, how soon the pollen is available, etc.

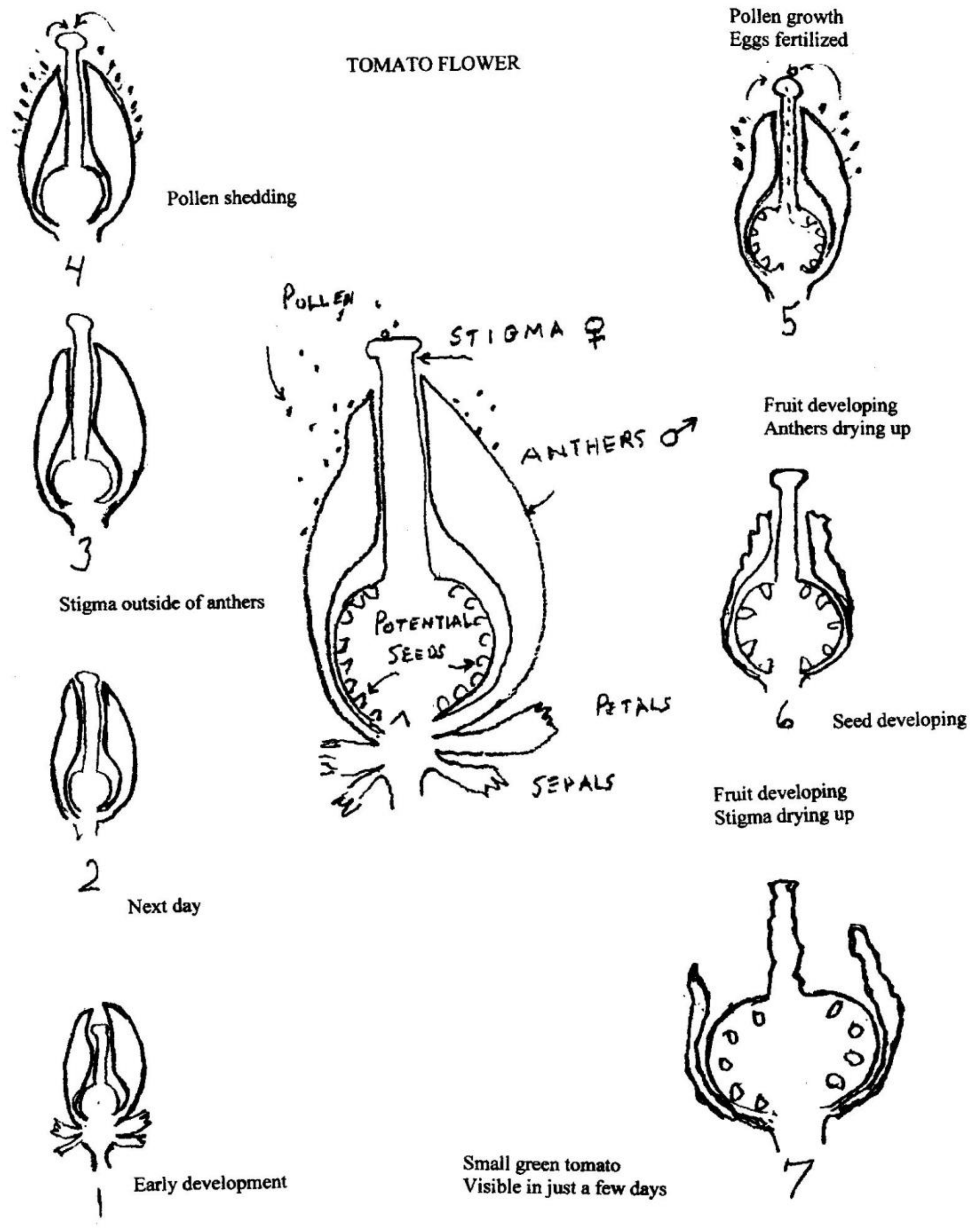
Seedless or Parthenocarpic Fruit: Seedless fruit do exist in many species. In these cases, the natural hormone is still involved and its production is often triggered by pollination even though fertilization of a seed does not occur. Some varieties of tomato may form fruit without having to be pollinated. These are called "parthenocarpic" varieties. Many greenhouse varieties are partially parthenocarpic and will set and develop fruit along with many seeds. Another issue is the "juicy matrix" that surrounds each seed. For varieties that are totally parthenocarpic, the juicy matrix is missing and the fruit tends to be hard, rather dry inside and less appealing. In short, the more seeds that can be developed the better the fruit quality, flavor and size.

Diagnosing Problems:

- One or two small fruit ripens in a cluster with normal sized fruit. Answer: if cut open the small fruit will probably contain only a few seeds. This is the result of poor pollination.
- A cluster with many poorly developed fruit. Answer: One must think back what was happening during the period when this cluster was forming and its flowers opening. One possible answer is that the area may have experienced an extremely hot period and flowers were killed. Possibly, the grower left the pollination in the hands of uninterested parties and it was not accomplished. If this symptom is

exhibited on many plants at the same stage of development, look for weather related issues or possibly something that the grower did….spray injury, etc. Another reason to keep good records.

SEE APPENDIX:


TOMATO FLOWER
Pollen shedding
4
3
Stigma outside of anthers
2
Next day
1
Early development
POLLEN
STIGMA ♀
ANTHERS ♂
POTENTIAL SEEDS
PETALS
SEPALS
Pollen growth
Eggs fertilized
5
Fruit developing
Anthers drying up
6
Seed developing
Fruit developing
Stigma drying up
Small green tomato
Visible in just a few days
7

BLOSSOM END ROT:

Symptom: The symptom of BER is that the blossom end (bottom) of the tomato begins to die and turns tan then brown or black. Blossom end rot is merely a shortage of calcium and can be corrected easily and inexpensively. Similar conditions can exist in related species such as pepper and eggplant however the discoloration will appear on the lower sides of the fruit as opposed to the blossom end as in tomato.

Conditions That Promote BER:

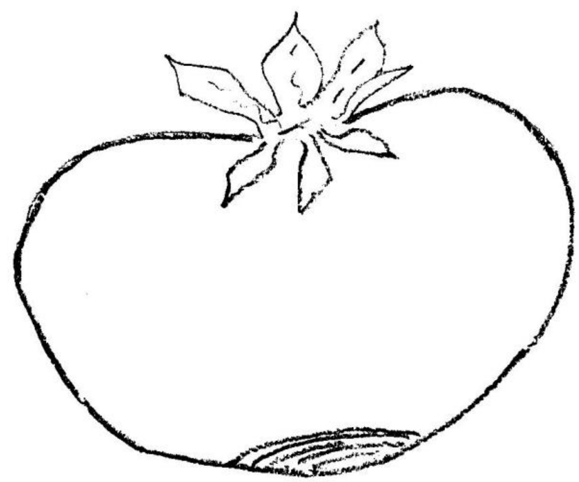
- The primary cause is a deficiency of calcium.
- Extremely rapid grown of fruit which results in a large demand for calcium over a short period of time. This normally is seen late in the crops development when the plants hold many fruit. It is also common in field grown tomatoes when late in the crop there are many maturing at the same time.
- Low soil pH. This results in calcium being in a very low supply and availability.
- Extremely high levels of soil magnesium (Mg) relative to the calcium level. These two elements are taken into the plant by the same mechanism. When either one is in an excess quantity relative to the other, the opposite one will become deficient in the plant. In short, a high magnesium level will promote a calcium deficiency and high calcium will promote a magnesium deficiency. A balance of 5 to10:1 calcium:magnesium is desired.
- Slow root growth which can be promoted by root disease, low soil oxygen, over watering, soil compaction. Since both calcium and magnesium are taken up right near the root tip, if the roots are not actively growing and being pushed through the soil, a deficiency can easily occur. Low oxygen, too wet, too dry, disease, etc. can all promote slow root growth and thus BER.

BER Correction: use one of the following.

- Application of lime or dolomitic lime prior to planting (dolomite is a mixture of calcium and magnesium carbonates and is the preferred product). For soil that has had no lime or dolomitic lime added previously, apply approximately 2 cups (500 grams total) per each square meter of bed and mix to a depth of 20-25 cm.
- Lime or dolomite can be added to the soil surface after planting but it requires a great deal of irrigation water to move it into the root zone since both products are very insoluble.
- Spray foliage with calcium nitrate in water (2 grams/liter). Spray on a cool day and repeat weekly until the end of the crop. For greenhouses tomatoes spray once a week and twice weekly for field grown tomatoes.
- Spray foliage with calcium chloride in water (about 1 gram/liter). Spray on a cool day and repeat as above until the end of the crop. Since chloride containing fertilizers appear to easily cause burning of foliage, it is strongly suggested that a few plants be sprayed as a trial. Again, always spray when it is cool, cloudy, etc. High temperatures and bright sunshine will help bring about foliar burning.

- The following year, additional dolomitic lime should be applied. If BER does re-occur, add dolomite or lime immediately and irrigate. In addition spray calcium using one of the two materials mentioned above, directly to the foliage.

BLOSSOM END ROT



Other Fruit Problems:

Fruit Cracking: Fruit cracking is often genetic with some varieties exhibiting many cracked fruit while others have very few. Extreme hot and cold weather result in the fruit growing and stopping. Cracking is most often caused by allowing plants to dry out thus allowing the fruit to stop enlarging. The shoulder of the fruit is the first to stop growing under normal conditions. When this occurs the shoulder skin quits growing and when the plants are again watered, the fruit attempts to further enlarge and merely splits. Soil moisture must be maintained at an adequate level without resulting in soil saturation.

Yellow or Brown Sides or Shoulders: This is most often due to excess heat. In short, it is often called sunburn or sun scaled. The symptom will be most often seen on a portion of the fruit directly exposed to and perpendicular to the sun from noon to 3 PM….the hottest and brightest part of the day.

Green Shoulder: This is a common genetic disorder that merely prevents the shoulder from ripening. Nothing generally can be done.

Holes: Mice often will feed on tomatoes and other greenhouse and field produced fruit.

SOILS AND THEIR PROPERTIES:

Constituents: Other than nutrients and water, soils are made up of sand, silt, clay and organic matter. Scientists have developed names for various mixtures of these materials. Generally speaking soils termed as "Loams" generally have the best overall characteristics, i.e. nutrient hold ability, water holding, drainage capacity and air space after drainage. See Appendix ( ) Soil Triangle.

Air and Water Relations: Sand particles are large compared to the other constituents. Clay particles are so small that an electron microscope must be used to see them. When soils are irrigated each particle becomes surrounded by a film of water. If the soil particles are very small as with clay there is no space left for air.

Fill a clear plastic bottle with fine sand and another with very coarse sand. Totally fill the bottles with water and then turn them up side down and allow the water to drain out slowly. Note the size and number of air spaces between the particles. The same relationship occurs in soil, however, with exceptionally small particles such as silt and clay, almost no air space is left between the particles.

One other characteristic is that clay particles contain many negatively (-) charged sites on their surface. Silt on the other hand has only a few and sand has essentially none. Organic matter also has many (-) sites and these tend to increase as organic matter decomposes.

These negatively (-) charged sites can old positively (+) charged fertilizers (just like magnets) and prevent them from being washed away. Negatively (-) charged fertilizers on the other hand are easily lost due to leaching.

Soils high in clay hold a great deal of water and nutrients but the oxygen content is so small that crop growth is very poor. Silty soils hold only a small amount of nutrients, a fair amount of water and a little more air than clay. Sands dry out very fast, hold no nutrients and not much air particularly if they are fine sands.

Organic matter holds a great deal of water, lots of nutrients and lots of air and is the best constituent to add to any native soil. In short, any soil can be improved by the addition of organic matter. Because of the varied sizes of the particles, it tends to physically open the ground and allow water to drain through easily and gasses such as oxygen and carbon dioxide to come and go freely.

Decomposition Rates: One must always keep in mind that all organic matter is not the same. Products such as tree bark, sawdust, rice hulls, wheat straw and others tend to decompose slowly. Peat moss and coco-peat decompose rapidly with most cattle manures being intermediate. Therefore when adding any of these to existing soils, one should think about what the soil will be like 6 or 12 months in the future.

The bacteria and fungi that decompose (eat) OM require a great deal of nitrogen in their diet. In addition, they are much more efficient in taking nitrogen out of the soil and will leave crops looking pretty hungry. In short, you are growing two crops at once and can only see one of them. For this reason, whenever a large quantity of OM is added to soil, additional nitrogen should be added at the same time. It often takes about 4-6 weeks for the fungi and bacteria to reach their maximum populations. At this point the nitrogen drain on the soil will end assuming added nitrogen has been sufficient. During this period additional nitrogen should be added every 5 to 7 days. Following this period, however, fertilize as you would normally for the existing crop.

Manures usually contain nitrogen however, if the manure has received a great deal of rain, most of the water soluble nutrients will be gone. Cattle manure generally contains only small amounts of immediately useable nutrients. With time and decomposition, additional nutrients will be available for crop growth. In short, manures act like slow-release fertilizers.

Poultry manure usually contains many times the water soluble nutrient levels of cattle manure. For this reason, only small quantities should be used at one time and generally are applied to the soil surface and allow rain or irrigation water to move the nutrients into the soil.

Soil pH: With 7 being neutral, slightly acid soils are preferred for most crops (5.5-6.5). pH of 6 to 6.5 is best for tomato.

Worn Out Soils: Any soil that is "worn out" can be recovered by adding the deficient nutrients and large amounts of OM.

BASIC FERTILIZERS:

Fertilizers: As mentioned above most fertilizers when dissolved in water come apart into positive (+) cations and (-) charged anions. For example: table salt is sodium chloride: + sodium, - chloride.

If the two word name of a fertilizer is used, the first word represents the (+) ion and the second word represents the (-) ion. Examples: ammonium nitrate, di-ammonium phosphate (DAP), mono-ammonium phosphate (MAP), potassium chloride, ammonium sulfate, iron sulfate, etc.

The Magnetic Effect: Similar to magnets, these (-) charged soil particles attract the (+) charge fertilizers and hold them much like a fertilizer bank. Negatively (-) charged fertilizers tend to wash away particularly with heavy irrigations or during rain storms. Nitrate nitrogen, sulfur, boron and molybdenum are is easily lost with too much watering. Phosphorus is also found in the negative list but its solubility is so low that it is not easily lost. All the rest of the fertilizers carry a positive (+) charge and can be held to the soil and organic matter as described, i.e. ammonia, potassium, calcium, magnesium, iron, copper, zinc, and manganese.

As roots grow through the soil they trade hydrogen (+) for other (+) charged nutrients. This is called cation exchange capacity or CEC. Therefore, soils with good trading ability (or CEC) usually also have high organic matter content, higher soil oxygen, hold more available water, prevent nutrients from washing away and produce better crops at lower costs.

Once all of the negatively charged sites are filled, (the nutrient bank is full) applying additional soluble fertilizer will often burn root tips and leaves. Therefore over fertilization is easily done in sandy soils but much more difficult in highly organic or clay soils. Excessive fertilizer will actually draw water out of plant roots thus killing them.

Electrical Conductivity or (EC): Since soils and fertilizers interact through (+) and (-) characteristics it is only reasonable that the quantity of nutrients (actually the total of all ions) in the soil can be measured electronically. As mentioned above, when too much fertilizer is added to plant beds roots are often killed. Similarly, if dissolved in water and sprayed on foliage, leaves may also show burning. For general information, EC values (dS/m) are measured using several different units. Values from 0 to 3 are generally good for crops; above 4 often begin to cause injury. Some crops are more tolerant than others.

If one reads information from Australia or New Zealand, a new term will be seen, Concentration Factor (CF). This is merely the EC value time 10. An EC of 2.0 would be presented as CF 20.

Plant Nutrients:

- Major nutrients: Nitrogen (N), Phosphorus (P), Potassium (K)
- Secondary nutrients: Calcium (Ca), Magnesium (Mg), Sulfur (S)
- Minor nutrients: Iron (ferrous) (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Molybdenum (Mo), Boron (B), Silicon (Si). As science continues to move ahead more will probably be added. These are also referred to as "trace elements".

Plants need all of the above including Carbon (C), Oxygen (O), and Hydrogen (H) and make their own vitamins.

The Fertilizer Bag: Fertilizer bags normally list 3 numbers. These are percentage values of Nitrogen, Phosphorus, and Potassium (NPK) in that order. Sometimes you will also see "TE" which indicates that the fertilizer also contains the trace or minor elements. A fertilizer listed as a 10-10-10 contains only half as much NPK as one listed as a 20-20-20. In most cases purchasing the higher analysis materials will be cheaper in the long run.

Fertilizer Formulations: Fertilizer may be soluble or insoluble in water. This depends on their individual ingredients and how they are formulated. Many bagged materials contain both soluble and insoluble materials. The grower can only determine this by reading all of the labeled information. Unfortunately, some suppliers do not list ingredients.

Slow-release Fertilizers: Slow-release fertilizers are formulated to dissolve very slowly. There are several types. Some require bacterial breakdown into smaller units others are formulated to dissolve extremely slowly or may be plastic coated. The plastic coated materials have small holes in the coating. Water moves into the granule, dissolves the fertilizer and slowly moves it back out into the soil. By varying the thickness of the plastic coating these products may be formulated to provide nutrients over periods as long as a year. These are not recommended for tomato or field production mainly because of their high cost but are often used by those producing flowering potted plants.

Soluble vs. Insoluble Fertilizers: Very insoluble fertilizers are products such as Single Super (0-20-0), Treble Super Phosphate (0-45-0), Lime, and Dolomitic Lime.

Very soluble products are Ammonium Nitrate, Calcium Nitrate, Ammonium Sulfate, Potassium Chloride, Potassium Nitrate and other. Most of the minor or trace elements are formulated in both soluble (Soluble Trace Element Mix) and insoluble forms (fritted trace elements). The latter product is made by mixing minor elements into molten glass. The glass is then ground into a very fine powder which dissolves very slowly.

Trace or Minor Elements: These are products such as Iron, Copper, Zinc and Manganese Sulfates, Sodium Borate, Sodium Molybdate and others. Most are water soluble and can be applied as foliar sprays. Caution however, all minor elements are used by plant in very small quantities….higher concentrations can be lethal.

Chelated Fertilizers: Chelated or sequestered fertilizers are large organic compounds that surround and protect nutrient elements. For example, in high pH soils, applied iron (iron sulfate) is quickly tied up in the soil and becomes unavailable to crops. By applying iron as a chelated product, the soil has no effect on it and roots will readily adsorb it. They can also be applied as foliar sprays and are quite expensive. These are further described in APPENDIX…..xxxxxxxxxxx

Foliar Application of Fertilizers:

Any soluble fertilizer can be applied as a foliar spray. The critical factors have to do with concentration, and other factors that directly affect the leaves. For example, don't spray in the hottest part of the day, choose a cool or cloudy day, take care to use proper concentration.

When applying primary or secondary nutrients, N, P, K, Ca, Mg, S, dissolve 1g per liter of water. Example: 1 g of product (ammonium sulfate) in 1 liter of water. Essentially, any element can be applied at the rate of 1 gram per liter of water.

When applying trace elements or minor elements particularly in the chelated form, it is suggested to cut any printed recommendation in half.

One author suggests that many elements are taken into the plant quite slowly. For example, 50% uptake: calcium 10-50 hours, phosphorus 5-7 days, potassium 10-20 hours, zinc 1-2 days, iron 10-20 days, magnesium 10-20 hours and urea nitrogen 1-2 hours. This data would further suggest that spraying water on the foliage early each day following a nutrient spray application would improve total uptake. But caution, no wet foliage late in the day!

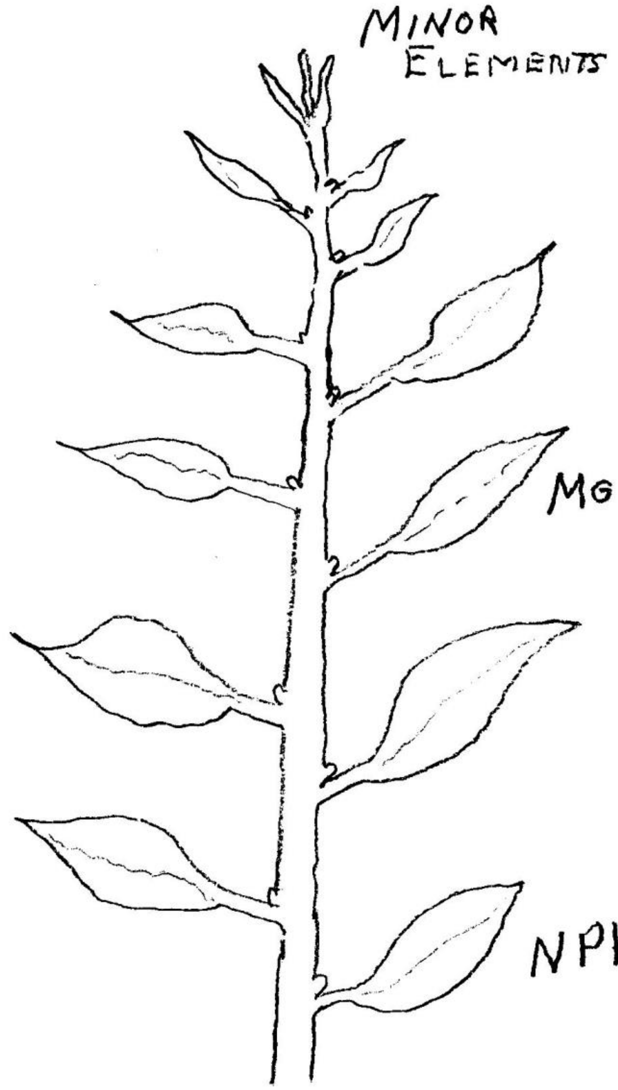
For blossom end rot use calcium nitrate sprayed at 2 g/l or calcium chloride at 1 g/liter. Once BER is seen, calcium sprays should be continued at least weekly until the end of the crop.

NUTRIENT DEFICIENCIES AND LOCATIONS ON THE PLANT:

Nutrient Deficiency Symptoms and Plant Locations: When trying to diagnose nutritional or any other symptom, "location" of the symptom is the first and most important clue. Nitrogen, Phosphorus and Potassium (N, P, K) are "mobile elements". This means that if the plant is actively growing and none of these elements are available in sufficient quantities from the soil the plant will take them from the oldest leaves on the stem, move them to the terminal growing point or other growth areas (fruit, flowers, seeds) and use them over again.

Nitrogen: The deficiency symptom is a general light green color of the entire plant followed by the oldest leaves turning yellow as the N is removed from them.

Phosphorus: This shows up as a red or purple coloration of the veins on the lower side of the oldest leaves. This same symptom will also show on tomatoes during cold weather…don't get fooled. In crops such as maise, reddish or purplish strips will be seen first on the oldest leaves. Older leaves of strawberries and geranium will turn red under conditions of high light intensity and low nitrogen. As the nitrogen is removed from the old leaves, this reddish pigment is shown through the green pigment. It is usually a nitrogen deficiency.
Potassium: This deficiency appears as a burning (browning) of the edges of the oldest leaves. Sometimes one will see large dead blotches on oldest leaves.
Calcium: Calcium is covered in the section on Blossom End Rot which is a calcium deficiency. Foliar symptoms of a calcium deficiency are almost never seen. In extreme cases the terminal bud will die and lateral buds begin to grow and then also die.
Magnesium: Magnesium deficiency normally is exhibited on newly expanded leaves. However, the symptoms can be anywhere throughout the middle of the plant. A general yellowing of the tissue between the leaf veins is the first symptom. As the deficiency gets worse the yellow areas will die and turn brown.
Minor or Trace Elements: All of the minor elements are "non-mobile". Their deficiencies always show in the new terminal growing leaves. These deficiencies normally appear as a yellowing of the new leaves. Careful… any root injury (too wet, too dry, soil compaction, disease, insects) can cause the same symptom…yellowing of terminal leaves. The symptoms are usually controlled by foliar sprays.


MINOR
ELEMENTS
MG
NPK

IRRIGATION METHODS:

General: Irrigation is one of the most important tasks that the grower does. The root is like an arm with the root tips being the fingers…all of the work is done by the tips, i.e., uptake of water and nutrient elements. Over-watering often kills root tips due to a lack of oxygen and may require many hours before new tips are formed. Growers with poorly drained soil must take care in irrigating and apply small amounts more frequently than with well drained soils.

Water Oxygen Supply: Over and over the need for soil oxygen is mentioned. Almost nothing is said regarding the oxygen supply of the irrigation water. Where water is pumped directly from streams, ponds or bore holes, changing the oxygen supply may prove difficult. However, if a grower is using any kind of holding tank they should consider attempting to increase the oxygen concentration in the water. Hot water contains far less oxygen than cold water. During hot months more water is used and saturation of the soil often occurs. Both of these situations result in low oxygen supplied to the roots. For these reason, water pumped into holding tanks should be allowed to fall a meter or more to help drive oxygen into the water. Any means of forcing air into the surface of the tank will help oxygenate the water.

Selecting Irrigation Methods: When selecting the type of irrigation method, keep in mind the major differences between drip and overhead. Where drip applies water slowly and in a narrow band, overhead covers the entire area. Soil composition and structure also play major roles in that water from a drip system moves almost straight down in sandy soils but broadens somewhat in fine textured soils like clays. In short, the water pattern is most often narrow and deep depending on soil type and amount applied.

Overhead irrigation will spread the water over a wide area in a uniform manner if sprinkler design instructions are followed. In this case, the water pattern is broad and shallow, again depending on the quantity applied.

When selecting a system, look at crop needs, depth of rooting, disease potential, compaction potential, wind, etc. since all of these should be considered.

Overhead Irrigation: Overhead irrigation is usually not recommended for use in greenhouses because of the potential for promoting foliar and other diseases. One exception is with cucumbers. The primary disease of cucumber is Powdery Mildew and it can start without a film of water on the leaves unlike most other diseases. Overhead irrigation is used to somewhat control this disease as well as help deter mites.

This method is usually less expensive to set up and operate but is not recommended for most crops. It has many disadvantages: long periods of wet foliage, entire floor is wetted, pounding effects of water droplets on soil leading to compaction, if applied to soon following a pesticide application the latter will be washed off, etc.

The irrigation world has developed many kinds of micro-sprinklers and in many cases these are very useful in the production of vegetable crops.

Drip Irrigation: This most chosen method of irrigation has many advantages, i.e. exact water placement, conservation of water, exact fertilizer placement and conservation, dry floors and foliage, no soil compaction, etc. Many types of products exist and no one type is best for all applications. Most systems operate at a maximum pressure of about 0.7 atmospheres or 10 pounds per square inch (psi). For these applications a head (vertical height of water above crop) of 70 cm = 1 psi or 7 meter head (height) will deliver maximum pressure. Many systems will work nicely with only 210+cm or 3+psi but the company should be consulted prior to purchase. Greenhouse floors should be reasonably level. Most systems are design to give quite uniform irrigation even with slight variations in tube height. (up to 12 inches or 30 cm).

Drip Tube Placement, Spacing: When irrigating, check frequently for soil moisture levels until you get experience. Too much water will bring on many problems; i.e. low oxygen, poor root growth, BER, root disease. Determine whether plants will be placed adjacent or staggered spacing before laying out the drip lines. Cut drip lines to match desired placement. Staggered placement usually results in less light competition by the plants.

Position drip lines 2-5 cm to the side of the stems. Initial watering will probably be best if done with a sprinkling can. Take care not to compact soil through the use of a large water volume hoses or walking on beds. After plant establishment (10 days) the lines should be moved farther from the stems (10-20cm). In a short time roots will fill the entire bed and water can be applied anywhere. Moving water lines further from the stems keeps excess water from direct contact of the stem in as much as disease often starts at this location.

Water Uniformity: Attempt to keep soil at a uniform moisture level. This of course, will require more frequent irrigations and possibly greater quantities during hot weather. Frequent small applications are usually better than less frequent large applications. This will require more labor but will reduce the chance of over-watering and the associated problems. If tomato soils are allowed to dry between watering the fruit skins harden and stop growing particularly on the shoulders. This is a primary cause of fruit cracking and can be reduced by maintaining uniform moisture. It is also variety related.
If a double row of drip tube is used, stagger the dripper spacing so as to apply the water more uniformly along the plant row.

Drip Tube and Tank Care: Tubes and tanks must be periodically cleaned. Bacteria and algae grow quickly and easily. For tanks, always keep a dark cover over the water so that light cannot penetrate. Algae need light and will not grow in a dark environment. Bacteria will usually grow in any wet location. Both of these will quickly plug drip lines making them useless.

Use water and household bleach 5:1 in a hand operated spray bottle or backpack spray. Check tank weekly by feeling the inside. A slippery feeling indicates bacterial growth. Spray with bleach/water mixture when the tank is empty. Allow to sit several hours or overnight. Rinse the sides of the tank and fill one quarter or a substantial amount of diluting water, open the ends of the drip supply lines and allow the bleach and water to flow through and out the ends. Refill the tank and irrigate. The amount of chlorine in the water will not be sufficient to cause plant damage.

Ends of drip lines are normally fitted with some type of plug. Periodically, open the ends and flush with a little chlorine and water. If the lines are left open until the tank has totally drained, little will be left in the drip lines to cause damage to the crops. Suggested intervals for cleaning…every 2-3 weeks especially when water is taken from a stream or pond. Water from a well (bore hole) is usually much cleaner but may contain algae if the top of the well has been left open. Tools, knives, and numerous items can be sterilized using water:bleach as low as 10:1 dilution.

SANITATION:

Disease: Greenhouse sanitation is critical in that fungi, bacteria and viruses move easily in these enclosed and damp areas. Workers should be encouraged to wash their hands often during the day and not to remove diseased plants until the last hour of the day.

Diseased plants should be pulled out of the soil, placed immediately in large plastic bags and removed from the greenhouse. Do not shake the soil off the roots…take it all out. This is done to prevent further spread of the disease as well as dropping diseased soil up and down the aisles. Worker should have clean clothes, boots and aprons if needed each day and should be trained often in the potential spread of disease.

As mentioned elsewhere, general pruning of excess shoots on all crops should be done early enough so that the small shoots will break when pulled with the fingers. If allow to grow they will require cutting with a knife. Viruses as well as other diseases are often carried in plant sap and transferred from plant to plant with “dirty” tools. Knives are often soaked in 50% alcohol or skim milk in order to kill viruses. Several knives are usually used so that they may be rotated between cuttings.

Irrigation Water: Irrigation water particularly if coming from a stream contains many diseases, weed seeds, algae and other unwanted items. If possible, use water from bore holes for starting seeds in that these sources are usually very clean and do not contain diseases.

Bacteria and Fungus Growth: Bacteria generally need wet conditions for several hours to infect a plant and prefer continuous wet conditions. Fungus spores are like seeds they need water, a proper temperature range and time in order to germinate and penetrate a leaf, flower or fruit. Most plant parts can become infected in 4-6 hours of continuous wet/warm conditions. For these reasons any activity that wets the leaves late in the day should not be considered. Wet leaves late in the day will remain wet all night. Drying of leaves prior to penetration of the germinating spores will kill the spore just as drying germinating seed is lethal.

Critical Greenhouse Conditions: Hot air contains more water than cold air. In the evening as the greenhouse cools rapidly, water from the high humidity condenses on everything in the building. You now have excellent conditions for disease development.

Potential Solutions:

- Always water early or mid-day so that the soil surface is as dry as possible.
- Never wet foliage late in the day.
- Just prior to dark, open all ventilation and attempt to exchange the hot humid air for cooler dryer air. This will greatly reduce condensation.
- Keep all weeds out of the greenhouse and preferably only allow grass to grow around the immediate greenhouse area. Several weeds closely related to tomato grow in this area. They are all susceptible to the same insects and diseases and become the source of disease infections, etc. Use a herbicide containing Glyphosate for killing both grass and broadleaf weeds. It has no residual life.
- For growers with long greenhouses (30 m), make sure that continuous side ventilators are part of the package. For growers with ridge and furrow (multiple building all connected) make sure the package contains roof as well as side ventilators.
- Clean ventilator screens of dust and algae to improve airflow.

Viruses: See also discussion relative to pruning tomatoes.

- Viruses are found in the seeds some crop plants but most often the source of greenhouse diseases are weeds in and around the building.
- Viruses are normally spread by sucking insects such as thrip, white fly, leaf hoppers, and others.
- Viruses are also spread by knives and pruners used to remove side shoots in tomatoes. Good growers will remove side shoots using their fingers when the shoots are very small (2-3cm). When these shoots get longer and harder, knives and clippers must be used. Viruses can be found in the plant sap or juice that sticks to the knives. When the grower cuts the next plant, the virus is spread. Entire houses are often destroyed because growers did not clean tools or hands once virus infected. Good growers use a small container containing alcohol and several knives. Once a plant is pruned, the knife goes into the alcohol and a new knife is used on the next plant.
- If a sick plant is found, take care in its removal. Pull and place it immediately in a plastic bag so that contaminated soil is not dropped along the way. Also wash shovel and other tools with water:bleach 5 to 10:1

Foot Baths: Chemicals such as chlorine that are used in foot baths are very subject to degradation by soil. These solutions should be changed daily or as soon as they get dirty. Suggest a 6-8: 1 of water : bleach. A 10:1 solution can be used on seeds and hands if washed off quickly…don't soak seeds in any bleach solution!

Insects: Growers should learn to identify all of the common insect and mite pests so that proper techniques can be used for their control. Learn their life cycles and to identify the various growth stages. Larval stages in most insects are the easiest to kill.

Control Procedures:

- No weeds in the greenhouse
- Try to keep only grass growing outside of the greenhouse and keep it cut short.
- Use screens on sides and ends and keep them clean of algae and dust.
- After walking through tall grass and other weeds, always brush off your clothes prior to entering the greenhouse. Make permanent pathways for workers so they don't have to walk through tall weeds and grasses.
- Visitors can usually see everything necessary from outside the building. Try to restrict entry to only those who need to work in them. Entry by each individual increases the possibility of insects entering on their clothes.

Specific Problems:

- White Fly, aphids and mealy bugs suck the plant sap from individual cells. This leaves a tiny white or light colored spot the size of a single cell. As their feeding continues, larger and larger dead areas appear. Their injury is often referred to as stippling as looks as if someone had punctured the leaf many times with a needle. Excess plant sap drips from these insects on to lower foliage and fruit leaving a clear sticky film. A fungus called Sooty Mold then takes over and begins to eat the sugary film and thus causes the area to turn black. The fungi don't actually eat the plant, only the droppings left by the above insects. Therefore, the control of blackened and sticky conditions goes back to controlling the aphids and white flies.
- Mites come in many kinds and forms. They most often attack new growth and suck juice out of the leave first along the major veins on the bottoms of leaves. As their numbers increase, they spread over the entire leaf and form webbing just like other spiders. A mite egg can hatch; grow to an adult capable of laying eggs again in 5-7 days during hot weather. For this reason, control measures must be carried out very frequently if control of a population is desired. Keep in mind that any spraying will never kill 100% and those that are left begin immediately re-populating the plant.
- Since most insects feed and live on the lower sides of leaves, turn the spray tip of your sprayer upwards. Even if a systemic material is used, direct contact with the spray material is most effective.

Other Problems:

- Slugs and snails can cause tremendous damage particularly if they get into seed beds. Their damage can often been identified by the slime trails. On the other hand, feeding marks are easily identified. The mouth parts of slugs and snails are similar to files. They essentially rub a hole in a leaf and often don't eat the far side thus leaving a thin film of tissue. Caterpillars and worm often start feeding on the edges of the leaf.

- Mice can also be very harmful particularly when seed is just germinating. If seed is noticed germinating in the evening and no seedlings are apparent in the morning, this is often due to a mouse. Sometimes a small stem will be left protruding just above the soil line.
- Chemical pesticides are available for both mice and slugs. Slugs and snails can also be prevented by placing a ring of lime around the beds of seedlings. The best slug/snail bait in the world is beer. Place a little beer (2 cm deep) in a low dish or jar lid. Place rocks around it so that dogs and cats can't get to it. Slugs and snails will crawl in drown and go out singing!

Pesticides:
- Always read the label.
- Obtain all the information you can get on products used frequently.
- Check the longevity of the pesticide. Many are very short lived (few days). This will help you to decide how often to reapply particularly when you begin with a large population of pests.
- High water pH (above 7) often destroys pesticides or greatly reduces their effectiveness. Check you water pH. Acids such as Phosphoric, Sulfuric and Nitric acids can be used to acidify the spray solution. Always acidify the water prior to adding the chemical. Sulfuric acid is usually preferred. Always add the acid to water, never water into acid and wear glasses. If water is applied to acid, spattering of the acid can cause severe burns to hands, eyes and clothing.
- Pesticides are poisons! They can be very injurious to you and even deadly if common sense precautions are not used.

Procedure:
- Always spray the undersides of leaves. Most insects live on the underside.
- Always spray when it is cool. If the concentration is a little too high or if the area is too hot, plant injury can occur.
- Always take care when handling and mixing pesticides…keep them off of yourself, your hands, etc. Wash immediately. Always wash clothes after spraying.
- Skin is somewhat of a barrier to poison absorption, however, a man's scrotium will adsorb chemicals 100 times faster than the skin of hands and arms. If you spill a chemical on yourself, take your clothes off immediately and wash thoroughly….don't even look around to see who's watching….clothes off immediately!!!!

Pesticide Decomposition: The longevity of a pesticide or its effectiveness varies greatly from one product to another. Products such as Malathion loose effectiveness in about 12 hours when the temperature is high. Most pesticides on the market today are only effective for a few days at the most. They then decompose into many other chemical products and continue to decompose. There are only a few products that have any long lasting properties. In short, they do not exist "forever" as some would like us to believe! However, this is no reason to be careless!

Decomposition of pesticides is brought about by many factors depending on the chemical. The following factors are known to cause pesticide decomposition: sunlight, water, fungi, bacteria, soil and high pH water.

KEEP RECORDS:

Every grower should have a daily record book in which they record planting information, spraying, fertilizing – how much and what analysis, weather, sun, rainfall, wind, purchases, prices, yield, and much more. Records come in very handy when weeks or months into the future a problem develops and can be traced to a grower's activity or to weather. When the time comes to start the next crops, you will have reference material as to what you did and the results. Memory is just not good enough!

APPENDICES

APPENDIX: 1

INITIAL FERTILIZATION RATES FOR GREENHOUSE AND FIELD BEDS:

Drip Irrigation Fertilization:

When irrigating through an irrigation system, many different programs may be used. For example, some growers feed with every watering, some once a week, twice a week, every two weeks, etc. In each case the fertilizer concentration changes although the ratio between the various nutrients generally remains the same. However, during the cropping period the various levels of nutrients also need to change. For example …feeding with every watering:

During the vegetative stage (no flowers or fruit) which lasts only a couple of weeks, a concentration such as the following is used:

- Feed at 200 ppm N, P, K. Phosphorus has already been added to the soil, but roots are not as yet well developed. Therefore it is recommended to use a soluble P such as in 20-20-20 or 17-17-17 for the first week or two.

As fruit development begins, change the mixture and add more K.

- Feed at the rate of 200 ppm N, 0 ppm P and 300 ppm K.

After another 3-4 weeks change the mixture again and add more K.

- Feed 200 ppm N, 0 ppm P and 350 ppm K

At the end of the crop, reduce N and totally drop all N the last several weeks. Feed K at 350 ppm until the end.

After 5-6 irrigations using fertilizer in the water, use only plain water to flush out the lines and the soil. Continuous feeding without using plain water periodically will often cause a fertilizer buildup in the soil that can injure the crops. In short, wash out the excess fertilizers periodically.

TO DEVELOP 100 PPM (Same as 100 milligrams per liter) FROM EACH FERTILZER:

1:1,000,000 or 1 part per million or 1 ppm or 1 mg /liter

Divide the number of ppm desired by the percentage of the element in the fertilizer bag (% changed to a decimal….17% = 17/100 or 0.17

For a 17-17-17 fertilizer, to develop 100 ppm N, P, K.

100 ppm /.17 = 588 mg/l of water

TO DEVELOP 100 mg/l or PARTS PER MILLION (ppm)

Analysis	mg/liter	N	P	K in ppm or mg/l
17-17-17	588	100	100	100
20-20-20	500	100	100	100
46-0-0 (Urea)	217	100	0	0
34-0-0 (Ammonium Nitrate)	294	100	0	0
21-0-0 (Ammonium Sulfate)	476	100		
0-0-50 (Potassium Sulfate)	200	0	0	100
0-0-60 (Potassium Chloride)	167	0	0	100
15-0-0 (Calcium Nitrate)	667	100	0	0

588 mg of 17-17-17 dissolved in one liter of water will supply 100 ppm of N,P,and K.

If you are using a 300 liter tank: 588mg x 300 = 176400 mg or 176.4 grams will supply 100ppm of each (N, P, K).

APPENDIX: 2

CROP FERTILIZATION USING WEIGHT VS. VOLUME CALCULATIONS:

Many fertilizers weight very close to the weight of water. Because of this, growers can use volume measures and be quite close to actually weighed products.

For practical purposes consider 1gram = 1 ml = 1 cc. Therefore it is suggested that growers purchase several small plastic or glass measuring cups. These can be used to measure quite accurately. Likewise, missing a measurement by a few grams one way or the other will not cause any problems.

For every 10 sq.m of bed, apply the following as a dry fertilizer and then spade the materials into the soil. Initial Fertilization for Greenhouse Beds: (Based on 10 sq.m of bed)

Lime or dolomitic lime:	24 (250 ml cups) per bed	(6 kg)
Single Super Phosphate (0-20-0)	12 cups per bed	(3 kg)
Potassium Sulfate or Chloride (0-0-50 or 60)	3 cups	(750 g)

Ammonium Nitrate (34-0-0) 2 cups (500 g) or Ammonium Sulfate (21-0-0) 3 cups (750 g).

Completely spade the bed to a depth of 25-30 cm
Level and irrigate carefully not to compact the soil. Continue to irrigate a small amount daily until the entire bed is moist. This will allow the soluble materials to begin dissolving and become attached to soil and organic matter particles.

The above materials were selected because they are by far the least expensive forms of these fertilizers (Calcium, Magnesium from Dolomite, Phosphorus, Calcium and Sulfur from Super Phosphate, and Nitrogen).

Plant by opening a small hole, set the root ball and cover lightly with soil. Do not pack the soil! Irrigate the first few days using a sprinkler type watering can with SMALL holes. Large holes will only tend to pack the soil and reduce soil oxygen which is very essential following root injury during transplanting.

Some fertilizers supply two nutrients. When using these, one usually calculates the portion with the highest percentage first. Calculate looking for 100 ppm of the phosphate portion and calculate again looking for the nitrogen portion.

For example if we want 100 ppm N and 100 ppm P from Di-ammonium Phosphate and Ammonium Sulfate:

18-46-0 (Di-ammonium Phosphate) (100/.46 = 217 mg/l (all of the P)

18-46-0 (Di-ammonium Phosphate) (100/.18 = 556 mg/l (a portion of the N)

But since we are only going to use 217 mg then use a proportion formula and determine the amount of N in 217 mg. of DAP.

If 556 mg is to 100 ppm of nitrogen
As 217 mg is to X ppm of nitrogen

Cross multiply and divide as follows: 217 x 100 = 21700 then divide by 556 = X = 39mg
So by using 217 mg/liter of DAP we will get 100 ppm P and 39 ppm of N.

We need a total of 100 ppm of N so 100 – 39 = 61 ppm needed from another fertilizer.

Using the same technique you can pick up the remaining N from Ammonium Nitrate or Ammonium Sulfate, etc.

If we used Ammonium Sulfate: (100/.21 = 476 mg of N) We need only 61 ppm so
If 476 mg will give us 100 ppm N then
X will give us 61 ppm cross multiply….

476 x 61 = 3713 (x) 3713/100 = 37 mg/liter.

Therefore we need 217 mg of DAP + 37 mg of Ammonium Sulfate to give us 100 ppm of P and N.

Fertilizing the crop:

During the vegetative stage: The following would be used to feed at every watering. However, about every 4-6 irrigations the grower should use only plain water with no fertilizer (mentioned above).

To feed at 200 ppm N, P and K using 17-17-17 =

100 ppm x .17 = (588 mg/l = 100 ppm) so 588 x 2 = 1176 x 300 liter tank = 352800 mg or 353 g/tank

During early fruit development:
Feed 200 ppm N and 300 ppm K.

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 2 = 588 mg/l x 300 liter tank = 176400 mg or 176.4 grams
plus
100 ppm K from Potassium Chloride = (167 mg/l = 100 ppm) so 167 x 3 = 501 mg/l x 300 liter tank = 150300 mg or 150.3 grams
These are both dissolved and placed in the tank of 300 liters of water.

Maximum fruit development:
To feed at 200 ppm N and 350 ppm K the grower would need the following:

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 2 = 588 mg/l x 300 liter tank = 176400 mg or 176.4 grams
plus
350 ppm K from Potassium Chloride + (167mg = 100ppm) so 167 x 3.5 = 584.5 mg x 300 liter tank = 175350 mg or 175.35 grams.
These are both dissolved and placed in the 300 liter tank.

Late fruit development…end of crop:
To feed at 150 ppm N plus 350 ppm K

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 1.5 = 441 mg/liter x 300 liter tank = 132300 mg or 132.3 grams
plus
100 ppm K from Potassium Chloride = (167mg = 100ppm) so 167 x 3.5 = 584.5 mg x 300 liter tank = 175350 mg or 175.35 grams.
These are both dissolved and placed in the 300 liter tank. During the last 3 weeks of crops totally stop feeding N.

If the tank holds 300 liters and you wish to give each plant 250 ml or ¼ of a liter then the 300 liters will irrigate 1200 plants. This is probably sufficient for small plants. As they get larger a tank may only irrigate half this many….500 ml per plant with each irrigation. Each grower will have to determine how much water is sufficient considering plant size, temperature, soil, etc.

When dissolving fertilizer for injectors or drip systems, always dissolve the materials in a second container and then pour the dissolved portion into the main holding tank. Some fertilizers may contain impurities, others may be wax coated to prevent sticking together in the fertilizer bags. Always run everything through a filter prior to the drip system.

APPENDIX: 3

DRY FERTILIZER RATES AND APPROXIMATE EQUIVALENTS: (values rounded)

200 lbs per acre or 5 lbs per 1000 sq.ft. or 1 dry cup/100 sq.ft. (1 cup = 8 oz or nearly 250 cc) or 250 ml or cc per 1 square meter.

Very light field fertilization = 200 lbs / acre or 225 kg/hectare
Moderate field fertilization = 350-450 lbs. /acre or 400-500 kg/hectare
High rate field fertilization = 600-700 lbs. /acre or 675-800 kg/hectare

200 lbs/acre = 224 kg/hectare or one 250cc (dry fertilizer) cups /1 sq.meters)
400 lbs/acre = 448 kg/hectare or two 250 cc (dry fertilizer) cups /1 sq.meters

APPENDIX: 4

FERTILIZER MIXTURE FOR FIELD USE:

Although there are exceptions, most dry fertilizers weigh about the same as water. Exceptions are materials such as Potassium Chloride, Lime ($CaCO_3$) and Dolomitic Lime ($CaCO_3$ + $MgCO_3$) which are heavier than most. When using Potassium Chloride in a mix reduce the volume to about 2/3 to make up for its added weight. For this reason, fertilizers for field use can be measured on a volume basis and likewise mixed on a volume basis to obtain specific percentage mixes.

For example, one can mix the following and the percentages will not be scientifically accurate but will be sufficiently close for field use.

Using equal parts (cups, pounds, kg or any other value), make the following mixture.

3 parts Ammonium Sulfate	21-0-0	
	21-0-0	
	21-0-0	
1 part Treble Super Phosphate	0-45-0	
1 part Potassium Sulfate	0- 0-60	
Total	63-45-60	now divide by the number of parts (not fertilizers)

63-45-60 / 5 = approximately 13-9-12

A grower may want to make a relatively balance material such as a 12-12-12 or 15-15-15.

Mix the following:

2 Parts of Ammonium Nitrate	34-0-0
	34-0-0
3 Parts Super Phosphate	0-18-0
	0-18-0
	0-18-0
1Part Potassium Chloride	0-0-60

Total and divide by the number of parts: 68-54-60 divided by 6 = 11-9-10

One can therefore make up nearly any percentage mixture by blending base materials such as Ammonium Nitrate, Ammonium Sulfate, Urea, any Phosphate material and Potash materials such as Potassium Chloride, Potassium Sulfate or Magnesium Potassium Sulfate, etc.

Caution, since the particle sizes may differ considerably, the mixtures may tend to separate if much vibration is experienced during handling or in a mechanical spreader.

Also when using Potassium Chloride, reduce it volume to about 2/3 to account for its greater weight.

APPENDIX: 5

ANOTHER METHOD OF FERTILIZER CALCULATION:

When using part per million (ppm) one can use the following formula.

75 (a constant) x percent of the fertilizer expressed as a decimal (for example, ammonium nitrate 34% or 0.34) = the ppm of 1 oz of this fertilizer dissolved in 100 gallons of water.

75 x 0.34 = 25.5 ppm of N when 1 oz of ammonium nitrate is dissolved in 100 gal.

APPENDIX: 6

FERTILIZER CALCULATIONS (FERTCALC):

Now after all these calculations, if you have access to the internet, go to FERTCALC. You will find this program developed by the University of North Carolina, Horticulture Department staff, USA. This program can be downloaded and do basically all these calculations for you.

APPENDIX: 7

WATER QUALITY: ADJUSTING pH OF IRRIGATION WATER

Info. source: Dr. Hannah Mathers and Vaughn's Seed Co publications.

The total carbonates plus bicarbonates $(CO_2)^{-2}$ + $(HCO_3)^{-}$ equals the alkalinity of the water.

The alkalinity of the water also determines its buffering capacity. The higher the buffering, the more difficult it is to change pH.

Water containing less than 50 meq/l of alkalinity usually pose little problem.

Acid injection into irrigation water.

Formula: A x B x C= ounces of acid/1000 gal of water to adjust pH to approximately 6.4.

A is a factor determined by water pH

Water pH	A	Water pH	A
6.7	0.249	7.7	0.475
6.9	0.342	7.9	0.484
7.1	0.400	8.1	0.490
7.3	0.437	8.3	0.494
7.5	0.460	8.5	0.496

B = the sum of bicarbonate and carbonate expressed as milliequivalents/liter of water (meq).

This information will come from a water test.

C = A factor determined by the type of acid used.

Acid: 75% Phosphoric = 10.6
85% Phosphoric = 8.74
93% Sulfuric= 3.72
61.4% Nitric = 15.6

Example: (A) Water pH = 7.5 x (B) (carbonates + bicarbonates) value 3.4 meq/l x C (75% Phosphoric Acid) =

A x B x C = ounces of acid/1000 gal of water to bring the water to pH 6.4

0.460 x 3.4 x 10.6 = 16.5 oz of 75% Phosphoric acid /1000 gal of water.

Nutrients added to irrigation water using the above acids.

1 oz 75% Phosphoric acid /1000 gal of water delivers 2.8 ppm of P
1 oz 85% Phosphoric acid /1000 gal of water delivers 3.4 ppm of P
1 oz 93% Sulfuric acid / 1000 gal of water delivers 4.2 ppm of S

APPENDIX: 8

SALINITY OF IRRIGATION WATER: DESIRABLE RANGES

Electrical conductivity: EC

Usually measured as millimhos per centimerter: (mmhos/cm) which is equal to millisiemen (mS).

Millimhos per centimeter (mmhos/cm) has been renamed recently to decisiemens per meter (dS/m).

The values of the two units are equal; only the name was changed.

Total dissolved salts (TDS) is measured in parts per million (ppm).

The relationship between water's electrical conductivity (Ecw) and its total dissolved salts (TDS) is:

Ecw (in dS/m) x 640 = TDS (in ppm or mg/l)

Desirable Ranges for Specific Elements in Irrigation Water:

Set 1:	Upper Limit	Optimum Range
pH		5-7
EC general production,	1.25 dS/m	near 0
plugs and seedlings	0.75 dS/m	near 0
Phosphorus (P)	0.005-5 mg/l*	< 1 mg/l
Calcium (Ca)	120. mg/l	40-120 mg/l
Sulfate (SO4)	240 mg/l	24-240 mg/l
Alkalinity	240 mg/l	0-100 mg/l
Sodium (Na)	50 mg/l	0-30 mg/l
Boron (B)	0.8 mg/l	0.2-0.5 mg/l
Fluoride (F)	1.0 mg/l	0 (especially for sensitive crops such as lilies, freesia and some foliage items.)
Magnesium (Mg)	24 mg/l	6-24 mg/l
Chloride (Cl)	140 mg/l	0-50 mg/l
Bicarbonate Equivalent	150 mg/l **	30-50 mg/l

Set 2:

Nitrates (NO3)	5	mg/l	0-5 mg/l
Potassium (K)	10	mg/l	0.5-10 mg/l
Zinc (Zn)	2	mg/l	0.1-0.2 mg/l
Molybdenum (Mo)	0.07	mg/l	0.02-0.05 mg/l
Iron (Fe)	5	mg/l	1-2 mg/l
Copper (Cu)	0.2	mg/l	0.8-0.15 mg/l
Aluminum (Al)	5	mg/l	0-5.0 mg/l
Sodium Absorption Ratio (SAR)	4	mg/l	0-4 mg/l

*   1 mg/l = 1 ppm
** Acidification is usually required to correct pH if bicarbonate equivalent is above 50 mg/l.

APPENDIX: 9

INTERPRETATION OF SOLUBLE SALT LEVELS *

DILUTIONS **

1:2 Soil	1:2 Soilless	1:5 Soil	Saturated Paste Extract Soil & Soilless	Pour Thru & Press	Interpretation
0-0.25	0-?	0-0.10	0-0.75	0-1.0	Crops hungry
0.26-0.50	?-1.0 0	0.11-0.25	0.75-2	1.0-2.6	Low value, unless applied with every watering
1.00		.50			Maximum for planting seedlings and rooted cuttings
0.51-1.25	1.00-1.75	0.26-0.60	2-4	2.6-5.3	Good for most crops
1.26-1.75	1.76-2.25	0.61-0.80	----	----	Good for established crops
1.76-2.00	2.25-3.50	0.81-1.00	4-8	5.3-10	Dangerous to most crops
2.00+	3.50+	1.00+	8+	10+	Usually injurious or lethal

*** Electrical Conductivity (EC) levels are expressed as mmho/cm, which is equivalent to mS/cm and to dS/m.**

****Some labs will report these values as mho x 10 (to the minus 5)/cm. (1mmho/cm = 100 mho x 10 to the minus 5/cm).**

APPENDIX: 10

EFFECTS OF WATER pH ON PESTICIDES

GENERAL: Pesticides are decomposed or broken down by many things in the environment. Fungi, bacteria, sun light, oxygen, high temperature, water and the pH of water plays a very important role.

Alkaline spray water often results in the rapid decomposition of many pesticides. Usually water over pH 7 is quite detrimental to many pesticides. Buffer solutions are marketed in many countries that must be mixed with the spray solution prior to adding the pesticide. These materials generally lower pH to 6 or below and thus make the pesticide last longer and do a more complete job.

Following are just a few examples:

Common or Trade Name	Chemical or Technical Name	Comments/Rate of Hydrolysis Time for 50% to Decompose
Ambush/Pounce	Permethrin	Stable at pH 6 - 8
Aeracide	Aramite	Slow breakdown under alkaline conditions, rapid if lime is present.
Baytex	Fenthion	Incompatible with alkaline conditions.
Cygon	Dimethoate	pH 2=21 hrs, pH 6=12 hrs., pH 9=48min. Iron increases breakdown speed
Cythion	Malathion	pH 6=7.8 days, pH 7=3 days, pH 8=19 hrs. pH 10=2.4 hrs.
Diazinon	Diazinon	pH 5=31 days, pH 7.5=185 days, pH 9=136 days, stable near 7, avoid acid conditions.
Dursban	Chloropyrifos	pH 4.7=63 days, pH 6.9=35 days, pH 8.1=22 days, pH 10=7 days.
Orthene	Acephate	pH 3=65 days, pH 9=16 days

Sevin	**Carbaryl**	**pH 6=100-150 days, pH 7=24 to 30 days, pH 8=2 to 3 days, pH 9=1 day**
Vapona	**Dichlorvos**	**pH 7=8 hrs.**
Captan (fungicide)	**Captan**	**pH 4=32 hrs, pH 7=8.3 hrs, pH 10= 2 min.**
Roundup (herbicide)	**Glyphosate**	**Avoid alkaline conditions, best at pH 2.5**

APPENDIX: 11

MAINTAINING CLEAN DRIP IRRIGATION WATER

WATER QUALITY & TREATMENT

1. Because of small orifice size, slow flow rates and lower system pressures; drip lines are susceptible to clogging.

2. Algae, Ferrous Iron (called Iron) and Hydrogen Sulfide (called Sulfur) are among the most common clogging enemies.

3. A commercial water test should be performed for the three problems above as well as suspended solids and water pH. This commercial test is a small price to pay for protecting $200-$500 per acre investment.

4. The most successful agent for treating various clogging problems in drip lines is chlorine. It is generally used in one of three forms: liquid or gas chlorine, or sodium hypochlorite. Liquid chlorine and sodium hypochlorite are recommended because they are much safer to use.

5. No matter what form of chlorine is used; always inject it before the filters. This helps keep the filters cleaner as well as gives the filters a chance to remove any dead, suspended or precipitated materials in the water.

6. When using chlorine, there should be a free residual chlorine level of 1 to 2 ppm at the farthest end of the drip lines. Free chlorine is that chlorine which is left unused after it has finished interacting with the chemical and biological compounds in the water.

7. Chlorination is generally done at the end of the irrigation cycle. This is done to ensure that there will be free chlorine available in the drip lines to fight chemical or biological enemies that might arise between irrigations.

8. Free chlorine can be tested for with a Hach Chemical DPD Test Kit. It has been found to be an effective means for testing for free chlorine. Hach Chemical is located in Loveland, Colorado. Other chlorine test strips are also available.

9. The slide trap is another method that is used in conjunction with the DPD Test Kit. A slide trap is a piece of black polyethylene pipe (PE) or a piece of PVC pipe pained black with a slide mounted inside it.

10. Irrigate and chlorinate, then check the slide inside the trap 48 hours later for any growths. If there is an ochre color, iron is present, a clear slime would be sulfur and a dull green or brown growths would be algae.

11. If there is no slime or growths present, chlorination is adequate. Also, if there has been no irrigation in a while and these growths appear, then it is time to chlorinate again.

12. Algae == For algae, enough chlorine should be injected to arrive at a free chlorine count of 1-2 ppm in the first part of the irrigation cycle. Generally, 30-60 minute chloroination at these free chlorine levels once every 4-6 irrigation hours is sufficient to keep lines free from clogging. Sand filters are usually used with algae present in the water. You should always assume the presence of algae in any pond, stream or canal.

13. Iron == For treatment of iron, 1 ppm of chlorine is used for every 1 ppm of iron in the water. The chlorine oxidizes and precipitates the iron as well as kills the iron bacteria. It is actually the bacteria that create the iron-clogging problem. It acts upon the iron in such a way that forms a slime that can live on the oxygen in the water. It clogs the holes because of the size of the slime. Again, injection of chlorine should be enough so as to have 1-2 ppm free chlorine count. The same 40-60 minute chlorination at free chlorine levels every 4-6 irrigation hours also applies. A sand filter is used above 2.5 ppm iron, below this a screen filter is sufficient.

14. Sulfur == For treatment of sulfur, 9 ppm of chlorine is needed for every 1 ppm of sulfur in the water. The chlorine kills the sulfur bacteria and thus prevents slime growths. Injection should be enough so as to have 1-2 ppm free chlorine. Once the real chlorine level is reached, injections should be maintained for 40-60 minutes. This should be done every 4-6 irrigation hours. Screen filters are all that is needed for sulfur.

15. The reason for determining water pH, is that when pH is 7.5 or above, it takes nearly twice as much chlorine to do the job than if it were below 7.5.

16. To lower the pH of water, add some form of acid to the water. A consultation with the person or lab who did the water test could probably determine how much it would take to lower the water pH to the desired level.

17. Generally, muriatic acid (hydrochloric acid) or Sulfuric acid is used to lower pH. They are easier to use that phosphoric acid. The water should always be tested if Phosphoric acid is used in the drip system. Phosphoric acid, unless injected in the exact amount needed, will precipitate almost everything present in the water and cause clogging of the drip lines.

18. PVC and Lay-Flay should be cleaned and flushed every year before using again, Onehalf gallon of 68.6 % murataic acid per three acre block will clean out mains and sub mains. The reason for cleaning and flushing is that they often become coated with oil from the pump and protective coatings on fertilizers. If the lines are not cleaned, flakes will fall off and clog drip lines.

START UP PROCEDURE

Flushing Mains:

1. Flush your main lines first.

2. Flush the main lines for about 20 minutes with all valves to the submains closed at this time.

3. After flushing is completed, close the end and install at least a 1" valve for future flushing operations.

Flushing Submains:

1. Flush submains one at a time for 5-10 minutes.

2. This should be done without the supply tubes hooked into the Twinwall.

3. Now close the ends. PVC can be capped. Lay-Flay can e closed by folding the end 3 or 4 times and then in half. Next take an 8" sleeve of the same size Lay-Flat and slide it over the folded Lay-Flat. This will seal water tight when filled with water. This also makes it convenient for future flushing.

4. Lay-Flat ends can also be closed off by folding it once and putting one piece of short 2 x 4 on either side and squeezing the Lay-Flay shut with bolts and wing nuts.

Flushing The Drip Lines:

1. Flush the drip lines themselves until the water shows clear in each line.

2. This will help determine if there are any problem rows by showing whether the water is getting through all the lines or not.

Checking Pressures:

1. Once a system is turned on, let it run for about 20 minutes sod that any air in the system has a chance to work its way out.

2. After 20 minutes start checking your pressure gauges.

3. Start at the filter and check your pressure differential.

4. Proceed to the pressure gauges on your submains. These gauges should be located on the field side of your gate valve.

5. These gauges should be checked every time the system is turned on. First to check and see if they are even working, and second to see if the pressure is OK.

6. Pressure in the Twin-Wall can be checked with a pressure Gauge with probe. A small hole is pierced in the Twin-Wall and the probe is inserted. The Twin-Wall should be adjusted by installing the correct supply tube.

7. Walk through each block checking wetting patterns. Any kind of tears or leaks will appear after 30 minutes of operation time. The appropriate splices should then be made. If pressures in the drip line are still too high or low while pressure is the submains is correct, then the drip line pressure should be adjusted by installing the correct supply tube.

OPERATION

1. Always run the drip line after it is first set up. This will open a "mole hole" for the buried drip line and allow the system to work faster 2-3 months in the future when it is started up. It is also a good time to check for leaks and other problems that could have occurred during installation.

2. Some growers use their start up operation to germinate weeds in the soil, after which they come through and kill them.

3. You're newly established "mole hole" can collapse too. You will have to use you judgment as to what a heavy rain is, but in any case you should turn your system on shortly after a heavy rain.

4. Turning our system on during a heavy rain will accomplish two things. One, it will keep the "mole hole" open and prevent the soil from drying like concrete around the tubing. Two, it will keep the rain from driving the accumulated salts at the root's edge back into the root zone. It will cause the salts to leach out of the root zone and thus prevent plant damage.

5. Although most drip systems are designed to apply a given amount of water per acre per day, most growers do not water on a daily basis. They usually water every second or third day. So if acre inches per day call for the field to be irrigated two hours a day, it would have to be irrigated for 4 hours every second day or for 6 hours every third day. Obviously, earlier in the season you would water for shorter periods of time. If you irrigated every day, you would be keeping the soil moisture at maximum levels. In the event of any rain, your crop could be hurt by too much moisture. That is why most people use a 2-3 day watering schedule.

6. At the time transplants are placed, the drip line is usually run long enough to moisten the entire bed. This takes 6-8 hrs, though in some sandier soils it takes 10-12 hrs.

7. Do not rely on surface moisture on the bed to determine whether the crop is watered enough. If this is done, there is a good possibility the crop will be overwatered. Either take core samples or use soil tensiometers to determine if there is enough water.

CHOOSING COMPONENTS

Screen Filters:

1. 200 mesh screen filters are used as a primary filter when there are only small quantities of contaminants in the water.

2. If the water is really clean, the filter can be used at its rated capacity.

3. If the water is dirty and a screen filter can still be used, use the filter at 1/2 its rated capacity. This is done to help the screen filter do a lore effective job as well as to keep it from plugging up as quickly with contaminants.

4. Screen filters are normally backflushed or cleaned at 5-7 psi differential.

5. A clean screen filter will normally register 1-2 psi friction loss.

Sand Filters & Separators.

1. Sand filters are used when fine particulate and/or organic matter starts to show up (ie. fine sand, algae, silt, clay and iron).

2. Sand filters should be followed by enough screen filters to handle the GPM going through the sand filters. This is a safety precaution that should always be taken. It is done to prevent accidentally discharge sand from the sand filter getting into the drip lines during backflushing or other operations on the sand filter.

3. #16 Silica sand (.66 mm, 1.51 uniformity coefficient) will remove particles down to 75 microns in size. This has usually been sufficient to prevent clogging in Twin-Wall.

4. Sand filters should be backflushed at 10 PSI differential.

5. When the season is over, the sand filters should be drained.

6. If a sand filter was not drained when put away during the off season, algae or other biological build-up can clog the filter. To unclog the filter, pour 2-3 quarts of chlorine into the filter, fill it with water and let sit for 24 hrs. After this is done, backflush the filter until the water runs clean.

7. Sand separators are used when large amounts of sand and small stones are being pumped from the well.

Injectors:

1. Positive Displacement Pumps meter out materials by forcing it into the line. This provides a very accurate method of injection.

2. When corrosive materials will be used, corrosive resistant injectors should be chosen. Most corrosive resistant injectors are made of stainless steel, porcelain or PVC.

3. Whatever injector you choose, always choose the simplest. The simpler it is the less chance of breakdown there is and the cheaper repairs will be.

Gate Valves:

1. Use gate valves but do not use quick closing valves (i.e. ball valves or butterfly valves). A quick closing valve can cause a sudden surge in submains and drip lines that can damage the system.

Pressure Regulating Valves:

1. These are sometimes used for two reasons: a). They are used when pressure at the source is known to fluctuate widely, and b). They are used on submains to maintain a uniform pressure.

Fertilizer Injection:

1. Only 100 % water-soluble fertilizers should be used. Any other materials could clog the system.

2. The fertilizer should always be injected before the filters so that any undissolved particles can be filtered out.

3. Drip irrigation has a greater leaching affect on fertilizer than furrow irrigation. Phosphates and potash move much more with drip, necessitating the addition of these elements as well as nitrogen on a frequent basis.

4. The drip, however, places the fertilizer accurately and evenly in relation to the root zone of the plant. These frequent, accurate applications of water and fertilizer lead to a healthier plant because it is not stressed as much.

From: Chapin Watermatics, Inc., USA

APPENDIX: 12

CHANGING pH:

Because of a soils ability to hold nutrients as opposed to allowing them to wash away, changing pH in soils is highly dependent on soil type.

Pounds of limestone needed per acre as affected by soil type.

pH CHANGE DESIRED	SAND	SANDY LOAM	LOAM	SILT LOAM	CLAY LOAM
4.0-6.5	2,600	5,000	7,000	8,400	10,000
4.5-6.5	2,200	4,200	5,800	7,000	8,400
5.0-6.5	1,800	3,400	4,600	5,600	6,600
5.5-6.5	1,200	2,600	3,400	4,000	4,600
6.0-6.5	600	1,400	1,800	2,200	2,400

These changes may take several months to complete. When dealing with greenhouse crops in containers, KOH can be used to raise pH and most any acids can be used to reduce it quickly (H3PO4, HNO3, are the most common). Applied

APPENDIX: 13

BLOSSOM END ROT III

BLOSSOM END ROT OF TOMATO, PEPPER, EGGPLANT AND OTHER RELATED VEGETABLES

SYMPTOMS:

BER is characterized by a shriveling, browning and drying of fruit tissue primarily at the blossom end. Symptoms may be in multiple spots as in the case of peppers and eggplant but are usually found at a single site on tomato. Following the browning etc, various fungi or bacteria may enter the dead tissue and spread throughout the fruit.

CAUSES:

BER is caused by a deficiency of CALCIUM in the fruit; however, this is often made more sever by several other factors.

1. Low calcium level in the soil.

2. Low soil pH associated with low soil calcium.

3. High levels of soil magnesium often results in lower calcium uptake. These two elements are extremely similar in atomic size and weight. For this reason, plants apparently have difficulty telling the two apart. The calcium: magnesium ratio is often maintained between 6:1 to 3:1 and sometimes as high as 10:1 depending on the crops in question. Absolute ratios will differ from one crop to another as well as being influenced by environmental conditions.

If the ratios are far out of balance, one element can cause a reduced uptake of the other. In other words, very high calcium can cause a magnesium deficiency and vise versa. In tomato, peppers, and eggplant, it is recommended to keep the balance in the 6:1 to 3:1 ratio range.

4. High levels of other cations (+ changed elements such as ammonia {NH4+}, potassium (K+} and magnesium {Mg++}) can also promote lower uptake of calcium.

5. Extremely rapid growth rates as encountered in mid-summer often appear to bring on BER. When plants are growing very rapidly, the need for calcium throughout the plants' foliage as well as fruit is high. Unlike several other elements such as nitrogen, phosphorus and potassium, calcium, once used by the plants'

foliage, stems or fruit, cannot be moved to another site and used over again. For this reason, BER normally is exhibited in the newly developing fruit. The blossom end is the most rapidly developing area of the fruit and therefore it is the site of the deficiency.

6. During extremely hot weather, excessive irrigation is often used. If media particle size is too small, media remains saturated from one irrigation to the next. This in turn brings about low oxygen levels in the soil or artificial media in which the plants are growing.

(Hydroponic Culture) Polyethylene wrapped media blocks, planks or other named products often have sufficient air space under normal growing conditions. However, because of their shallow (7-10cm) depth, frequent irrigation can result in near saturated conditions.

Studies have shown that low oxygen levels greatly inhibit growth of root tips. Other studies indicate that calcium is taken up primarily at the root tip whereas other elements may be taken up further back along the root. Again, a combination of environmental and physical conditions brings about a low oxygen situation in which calcium uptake is less than needed and thus promotes BER.

7. In the case of hydroponic production, increased temperature of the nutrient solution reduces its ability to carry oxygen. Damming or ponding of the nutrient solution within the hydroponic system greatly reduces nutrient flow as well as its oxygen content and availability to the roots.

In short, almost any condition that puts plants into a stressful situation appears to promote BER; i.e. low Ca, high NH4, Mg or K, extremes of heat, excessive growth rates, excessive EC values, excessive wet or dry conditions, low oxygen content of soil or nutrient solution.

POTENTIAL CORRECTIONS:

Correction of BER can usually be accomplished by spraying a soluble calcium directly on the plant foliage (primarily upper or newly developing fruit and foliage). Products such as calcium nitrate, calcium chloride or calcium hydroxide can be used.

1. Calcium Nitrate: This is usually the first choice of most growers because of its availability. However, in many cases, the added nitrogen is not needed in that it also promotes excessive foliage development and further complicates the issue.

Apply as a foliage spray of 1 lb/100 gals. of water (0.5 kg/500 liters). Use lower rates during extremely hot weather. Always apply early in the morning or very late in the day to avoid burning. Where extreme environmental conditions persist and

plants are large and carrying large quantities of fruit, spray applications may be necessary two to three times each week and continue until cooler growing condition return.

2. Calcium Chloride: This material is used except where excessive chlorine exists in the native soil or in water supplies. Calcium Chloride is usually the preferred material for BER correction. Application rates should be one half that of calcium nitrate. Frequencies are similar to calcium nitrate.

3. Calcium Hydroxide: This is usually a grower's last choice because it is very caustic and difficult to handle. Apply only one half as much per application as the above materials, i.e. 0.5 lbs/100 gal or 0.25 kg/500 liters.

Lime (calcium carbonate) or Dolomitic Lime (calcium carbonate + magnesium carbonate) or Gypsum (calcium sulfate) may be applied to the soil. These products dissolve very slowly thus any affects on the crop may take weeks or even months. These materials should be applied to the soil and thoroughly mixed prior to planting. Lime and Dolomitic Lime will increase soil pH whereas Gypsum will have little or no effect on pH.

APPENDIX: 14

BASIC NUTRIENT SOURCES:

NITROGEN CONTAINING MATERIALS:

	*	Analysis	Product	Other Ingredients
•	*	46-0-0	Urea	
•	*	36-0-0	Urea-Sul	20% S
•	*	34-0-0	Ammonium Nitrate	
•	*	30-0-0	Ammonium Nitrate Sulfate	6% S
•	*	21-0-0	Ammonium Sulfate	24% S
•	*	15-0-0	Calcium Nitrate	20% Ca
•	*	13-0-44	Potassium Nitrate	
•	*	12-0-0	Ammonium Thio Sulfate (liquid)	26% S
•	*	32-0-0	Solution 32 (liquid, ll.25 lbs/gal, 3.58 lbs. N/gal)	
•		18-46-0	Diammonium Phosphate	
•		16-20-0	Monoammonium Phosphate	12% S
•		13-39-0	" "	6% S
•		11-48-0	" "	3% S
•		11-52-0	" "	3% S
•	*	12-61-0	Monoammonium Phosphate (technical grade)	
•	*	21-53-0	Diammonium Phosphate (technical grade)	

PHOSPHATE CONTAINING MATERIALS:

		Analysis	Product	Other Ingredients
•		0-18-0	Single Superphosphate	12% S
•		0-20-0	" "	10% S
•		0-25-0	" "	6% S
•		16-20-0	Monoammonium Phosphate	12% S
•		13-39-0	" "	6% S
•		11-48-0	" "	3% S
•		11-52-0	" "	3% S
•		0-45-0	Treble Superphosphate	3% S, 10% Ca
•	*	0-75-0	Phosphoric Acid (75%, 13.3 lbs/gal, 10 lbs P/gal)	
•	*	12-61-0	Monoammonium Phosphate (technical grade)	
•	*	21-53-0	Diammonium Phosphate (technical grade)	

see also the Phosphate containing materials in the Nitrogen section above)

POTASSIUM CONTAINING MATERIALS:

•	*	0-0-60	Potasium Chloride (Muriate of Potash)	
•		0-0-50	Potassium Sulfate	18% S
•	*	13-0-44	Potassium Nitrate	
•		0-0-20	Potassium/Magnesium Sulfate (Sul-Po-Mag)	22% S, 11% Mg
•		0-0-18	Kelp Meal	

(*) GENERALLY SOLUBLE IN WATER

BASIC NUTRIENT SOURCES

SULFATE OR SULFUR CONTAINING MATERIALS:

	*	Analysis	Product	Other Ingredients
•	*	36-0-0	Urea-Sul	20% S
•	*	30-0-0	Ammonium Nitrate Sulfate	6% S
•	*	21-0-0	Ammonium Sulfate	24% S
•	*	12-0-0	Ammonium Thio Sulfate (liquid)	26% S
•	*	32-0-0	Solution 32 (liquid, ll.25 lbs/gal, 3.58 lbs. N/gal)	
•		16-20-0	Monoammonium Phosphate	12% S
•		13-39-0	“ “	6% S
•		11-48-0	“ “	3% S
•		11-52-0	“ “	3% S
•		0-18-0	Single Superphosphate	12% S
•		0-20-0	“ “	10% S
•		0-25-0	“ “	6% S
•		0-45-0	Treble Superphosphate	3% S, 10% Ca
•		0-0-50	Potassium Sulfate	18% S
•		0-0-20	Potassium/Magnesium Sulfate (Sul-Po-Mag)	22% S, 11% Mg
•			Calcium Sulfate (gypsum)	12-15% S
•			Magnesium Sulfate (Epsom Salts)	13% S
•	*		Iron Sulfate	19% S, 20% Fe
•	*		Manganese Sulfate	14% S, 24-65% Mn
•	*		Copper Sulfate	13% S, 25% Cu

•	*	Aluminum Sulfate	14% S
•		Flowable Sulfur (6 lbs S/gal)	51% S
•		Lime Sulfur	24% S
•		Yellow Elemental Sulfur	30-100% S
•		Sulfuric Acid 75%	75% S

CALCIUM AND/OR MAGNESIUM CONTAINING MATERIALS:

• *	Analysis	Product	Other Ingredients	Neutralizing Value
• *	20% Ca, 15%	Calcium Nitrate		
• *	29% Ca	Calcium Chloride		
•	32% Ca	Ag Lime, Calcium Carbonate, Limestone		75-90
• *	60-80% Ca	Calcium Hydroxide, Slacked or Hydrated Lime		115-136
•	43% Ca	Calcium Oxide, Unslacked, Burned or Quick Lime		173-179
•	30% Ca	Cottrell Lime (Stack dust from Concrete Plant)		85
•	30% Ca	Sugar Lime (contains much water)	(< 0.5% N, <1.0% P)	85
•	36% Mg	Magnesium Oxide		
•	24% Ca, 11% Mg	Dolomite (mix of Ca & Mg Carbonates)		100-105
•	11% Mg	Magnesium Sulfate	13% S	
•	11% Mg	Potassium Magnesium Sulfate (SulPoMag)	20% K, 22% S	

(* GENERALLY SOLUBLE IN WATER)

MINOR ELEMENTS: **Suggested Rates:**

• *	20% Fe	Iron Sulfate	0.5-1 lb/100 sq.ft or 0.25-0.5 g/ 10 sq. m.
• *	24-65% Mn	Manganese Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g / 10 sq. m.
• *	25% Cu	Copper Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g / 10 sq. m.
• *	22-35% Zn	Zinc Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g /10 sq. m.

- * 22% Mo Sodium Molybdate 0.05 oz/100 sq.ft. or 1.5 g / 10 sq. m.
- * 11% B Borax or Boric Acid 0.5-1 oz/100 sq.ft. or 14 - 28 g / 10 sq. m.
- * 20% B Solubor 0.5 oz/100 sq.ft. or 14 g / 10 sq. m.

(* GENERALLY SOLUBLE IN WATER)

All Minor Elements must be applied in very small quantities. Larger quantities or frequent applications can result in crop death.

Chelated minor elements: see manufacturer's directions

Fritted minor elements are available for most elements. These elements are dissolved in molten glass, ground and then applied as a very fine powder. The glass dissolves slowly thus giving a slow-release effect.

Since most or the above listed minor elements are soluble in water, they can be applied as a foliar spray. These are usually applied no more than every 6-8 weeks apart.

SLOW-RELEASE FERTILIZERS:

Slow-release fertilizers are produced in many ways. Many factors affect their release rate and this must be known by the grower or production disasters will occur. Following are just a few products.

Plastic Coated Materials: There are several types of plastic coated materials on the market. The release rate of some plastic coated materials is highly dependent on temperature. Microscopic holes in the plastic coating become larger as temperatures increase. Growers using these products inside of greenhouses, in tropical areas or during the hottest periods of the year must take into account faster release rates than are usually advertised.

Other plastic coated materials may not be as adversely affected by temperature. In order to have relatively even release rates over an extended period of time, some companies will use different plastics for their short term materials as opposed to their longer life materials.

Plastic coated granules of different sizes are sometimes used. Formulas using many small particles give a greater surface area than if the material was formulated with fewer large particles. Thus, the greater the surface area, the faster the release rate.

Some products are coated with sulfur to slow down their release, others merely dissolve very slowly. The bottom line is that a grower must understand how a product releases its fertilizers prior to their use! Once the product is applied, it is nearly impossible to remove. When starting to use a new product, apply it at several different rates on small areas and under different production circumstances (different times of the year, inside a greenhouse as opposed to outside use). From these trials, develop your own use rates.

APPENDIX: 15

SOLARIZATION: USING THE SUN FOR SOIL STERILIZATION

Heat is used in many commercial businesses for the purpose of pasteurizing or sterilizing objects, media, etc. Likewise, media used for starting seedlings is often pasteurized to eliminate disease as well as other unwanted seeds and insects.

Pasteurization of sowing media can be done either by placing media in an oven or by using the heat of the sun during mid- to late-summer.

Requirements:

- Media must be wet or moist for 1-2 weeks prior to heat treatment. This allows the resting stages of fungi and bacteria to begin growing. Resting stages are very resistant to heating.
- Media temperature must be raised to about 75 C - 165 F for 30 minutes. Using higher temperatures will often change the organic matter in the media to black carbon and this defeats the purpose of having it in the mixture.
- Following pasteurization cover the media so that no new weed seed can contaminate it.
- Make sure that "clean" tools (shovels, etc.) are used to handle newly pasteurized media.

Oven Pasteurization:

- Heat oven to about 100 C
- Place moist media in a shallow pan such as a cookie sheet. (3-5 cm in depth) Use of a shallow pan allows the media to heat rapidly.
- Use a cooking thermometer and periodically check media temperature. When the center of the media reaches 75 C- 165 F reduce oven temperature and hold at this temperature for 30 minutes.

Solar Pasteurization:

- For container media, place media on a sheet of plastic or a concrete area. Place no more than about 10 - 15 cm deep. The quicker it heats the easier it is to handle large amounts.
- For field soils, till several times to eliminate major weeds and large clods.
- Make sure the soil remains moist for 1 - 2 weeks prior to heating.
- Cover soil with either clear or black polyethylene, clear usually works best. This acts to hold the heat in and allows heat to reach pasteurization temperatures.

- Check periodically to determine the depth to which the required heating has occurred. In field situations, pasteurization may only occur to a depth of 5-10 cm. Since turning the soil with a tiller will bring new living weed seed to the surface, sow new seed without doing any tillage other than just breaking the surface.
- Following the required heating and time period, remove the treated soil and store in containers or under a cover so that new weed seed will not contaminate it.
- Use clean tools and do not allow individuals to walk on the clean soil. Use all precautions to keep it clear of contaminated tools, hands, boots, etc.

Many beneficial fungi and bacteria are not killed at the 70 C level and thus will continue to inoculate the media. If they are killed they normally return relatively quickly on their own.

APPENDIX: 16

SOIL AND MEDIA STERILIZATION:

As methyl bromide is being phased out around the world as a soil fumigant, many products are being investigated. Metam Sodium, chloropicrin or teargas is one of the primary materials currently in use. Another is the old practice of using steam.

For many years the practice involved injecting steam through downspout pipes with holes drilled in the sides for the steam to escape. The pipes were laid in beds of soil and covered by about 12-15 cm of soil. The entire bed was then covered with some type of tarp to help hold the steam. Bed temperatures were raised to 180F (82C) and held there for 30 minutes. Later, it was found that raising the temperature to only 165F (74C) was sufficient to kill pathogenic fungi and bacteria but allow many of the non-pathogenic fungi to remain. The current practice is to use the 165F (74C) for 30 minutes.

Using the higher temperature often created problems because of the release of manganese in the media which was then toxic to immediately planted crops. Using the lower temperature has greatly reduced this problem.

APPENDIX: 17

GROWING GREENHOUSE TOMATOES AND OTHER VEGETABLES IN CONTAINERS:

Growing crops in containers is an entirely different situation than in-ground or field production. The above ground environment remains the same but everything from the soil surface down changes drastically.

As mentioned in other aspects of this report, roots need oxygen just as all above ground growing parts. The major changes are brought about by putting media in a container. When growing in the ground, the water table may be only 2-3 meters or 100 meters below the soil surface. The container, on the other hand, makes an artificial water table often referred to as a “perched” water table (perched….as a bird perches on a limb).

This means that the media’s water content at the base of the container is just as wet as if it were sitting immediately on top of the soil water table many meters down. If one measures the quantity of water held at various levels above a water table you would find total saturation at the table. It would gradually hold less and less water with increased height. You can easily test this for yourself. Fill a kitchen sponge with water and lay it flat in your hand until it stops dripping. Next, turn the sponge on its side and you will see more water drain out. Next, turn the sponge on end so that the length of the water column is again increased. More water drains out!

You have not squeezed the sponge, merely changed the vertical length of the water column and each time drainage increased. The same thing occurs when media is placed in a container. The taller the container the dryer the media as you move above the base.

For example, if we had three containers, one 20 cm deep, one 40 cm and a third at 60 cm. All three could have the same volume. Irrigate the containers and allow them time to drain (nothing dripping out) then if we could measure the amount of water in all three this is what we would find.

- Wetness at the base of all three would be exactly the same.
- Wetness at the 20cm level of all three would be the same but less that at the bottom.
- Wetness at the 40 cm level of the last two would be the same but less than the moisture level at the 20 cm level.
- The wetness at the 60 cm level of the third container would be much less than that of the top of the 20 cm container.

Again, you can test this for yourself. Totally wet 4 or 5 new kitchen sponges and quickly stack them on top of each other. Pour some more water on the top sponge. Let the stack drain for a minute or so. Starting at the top, squeeze each sponge into a glass and collect the water. You will see that as you get closer to the bottom sponge the amount of water held increases greatly.

Now what does all of this have to do with growing a tomato or anything else in a container?

When any media is irrigated, each particle becomes surrounded by a tiny film of water. Soil particles, sand, silt and clay are so small that when they are close to a water table, there is essentially no space left for air. No air no root growth no plant!

All commercial container production world-wide is done in various mixtures usually containing a large percentage of organic waste products. Organic waste is used because it has many characteristic needed for good culture as well as being low in cost. An Appendix is included which shows what the air and water relationship is in many individual products as well as many 1:1 mixtures. The last item in the Appendix is one of the most costly mixes but it shows what all other mixtures try to duplicate.

1:1 peat and perlite……….Water Space (53%) and Air Space (23%)

A technique is shown how one can mix different media and actually measure the Water and Air Space in a container.

If you are contemplating growing in containers, choose a container of the same vertical height for doing the testing. The volume plays only a small role in this type of testing. Tomatoes, for example are often grown in rigid containers or black plastic bags. Approximately 8-10 liter bags work nicely (media depth about 25cm) Again, a grower located in an extremely hot country should use a taller container because they will usually tend to overwater during high temperature extremes. Growers in The Netherlands, Western Europe and North America often used artificial media in the form of plastic wrapped blocks about 5 cm high, 15 cm wide and 100 cm long. I have seen extremely poor root development during excessively hot weather just because they watered too often and kept the media totally saturated.

One should try to make a mixture that has the following characteristics:

- Since particle size of an organic waste product continues to get smaller as it decomposes, try to find something that decomposes slowly or not at all. Screened volcanic stone, sawdust, ground tree bark, sugar cane waste, rice hulls, chopped wheat straw. Each of these should be tested for a season before making a large planting.
- Add a small size organic waste to increase the water holding capacity. Shredded or composted manure, peat, etc.
- Do not add sand as this only increases weight.
- Perlite
- I don’t suggest vermiculite because it breaks down into much smaller pieces with time and also if it used over again.

When a mix is completed and ready for testing, try to come close to the following values:

Water holding capacity: 35-50%,   Air space: 15-20+ %

Also, keep the following in mind. Organic materials generally hold a great deal of water and nutrients. As they decompose their CEC or nutrient holding ability increases as well as the water holding ability. The air space begins to decrease as decomposition continues and particles get smaller.

Media temperature also increases well above what is found in the soil. Growers in extremely hot regions use plastic bags that are white on the outside and black on the inside.

Crop nutrition is very similar to soil application. Nutrient rich water can be used a single time and then discarded or reused and nutrients added every few days. This will not be discussed at this time. The above information on media is mentioned only to get growers to begin thinking about alternatives to soil culture. Several fungal root rots and various bacterial diseases are very common in this area and will increase with time. Many growers around the world have moved to soilless culture because of these problems that you are now facing.

One of the first media I would suggest looking at is a mixture of screened volcanic stone (2-6mm) mixed with peat or composted manure. This mixture could be used over several times and could also be chemically sterilized. The composted manure would gradually decompose to almost nothing.

APPENDIX: 18

DETERMINATION OF AIR AND WATER VOLUME PERCENTAGE FOR CONTAINER MEDIA

GENERAL OBSERVATIONS:

- **Roots need oxygen to function normally. For this reason mixtures of various media are used when growing in any type of container.**
- **When media is placed in a container, a "perched" water table forms at the bottom of the container. Media in this area remains totally saturated following irrigation. This total saturation greatly inhibits root development.**
- **Selection of ingredients used in a particular mix should be based on several factors.**

The media performs several functions;

- **Coarse products promote rapid drainage and increase air space;**
- **Fine textured products increases water holding capacity;**
- **Mineral products are usually heavy and add a great deal of weight to the final mix;**
- **Organic products are usually lighter than mineral products and like sponges hold a great deal of water not only on their surfaces but also internally. They usually have a great capacity to hold on to positively charge (+) nutrients called cations. Cations are nutrients such as the following: Ammonium, Potassium, Calcium, Magnesium, Iron, Manganese, Copper, and Zinc. Most mineral products other than clay have very little or no nutrient holding ability.**
- **Mineral products generally do not change in size, nutrient holding ability or water holding ability with time.**
- **Organic products continue to decompose with time and thus particles get smaller. Water holding capacity increases, nutrient-holding capacity increases but due to the decrease in particle size, air space decreases also.**
- **Some organics such as peat moss decompose more quickly than others, bark and wood containing materials, generally decompose quite slowly.**
- **Drainage in any mixture is controlled to a great degree by the texture or particle size of the various components of the mix. However, the vertical length of the water column in the container also plays a major role.**

For example, fill a sponge with water and lay it flat in your hand. When the dripping has stopped, turn the sponge on edge and more water will drain out. Finally, turn the sponge on end and you'll find that even more water comes out. Hole sizes in the sponge have not changed; no additional pressure was place on it; only the vertical length of the water column was increased.

Next, make a stack of four or five sponges and thoroughly wet them. Allow them to drain for five to ten minutes. Starting with the top sponge, squeeze the water into

individual cups. The top sponge yields a small amount of water and each succeeding sponge will yield more water until the last, which appears to be nearly totally saturated.

The above examples illustrate the importance of the length of the final water column.

- **Soil scientists tell us that any media that has an air volume of 8% or less will produce only grass.**
- **One of the most productive container media used worldwide is a 1:1 mixture of peat and coarse perlite. The peat acts to hold a great deal of water and nutrients; the perlite maintains good drainage and air space. Air space is usually around 25% and water space can be as high as 30-50%.**

The following will show how to quickly and easily measure the air and water space of any mixture of materials.

First, a few general rules:

- **The finest textured material (smallest particles) usually has the greatest overall effect on the mixture.**
- **When measuring, slight differences will occur between small diameter and very large diameter containers. For this reason, use small containers when checking mixture for use in small pots and large ones for large pots and bag culture.**
- **If you attempt to measure a material a second time while the media is still extremely wet, then the only reading will be the Air Space.**
- **Measurements such as these can be used to measure media after crops have been growing in them for a period of time. If this is done, try to use the existing growing container so as not to disturb the existing media structure and root system.**

PROCEEDURES FOR TESTING AIR AND WATER VOLUME PERCENTAGES

1. Select container(s) for testing.

2. Seal drainage holes with electrical tape.

3. Fill containers with water in order to measure their total volume. In the following example, we'll use 5000 ml for the total volume.

4. Empty container and fill with media mixture to be tested.

5. Compress slightly as you would if you were potting a new plant.

6. Using a measured amount of water, slowly add water down one side of the container until the water is level with the surface of the media. By adding to the side, air bubbles will be forced out as the water level rises. Pouring water in the center often traps air below.

7. Allow to sit for 5 minutes in order to thoroughly saturate all of the media.

8. A narrow knife or wire is often pushed into the mix to insure that all air bubble have risen to the surface.

9. Add water if necessary to bring water level back to the media surface.

10. The amount of water added is equal to the media's Total Porosity. This is the total of both the Water Space and the Air Space.

11. Remove a piece of tape from the bottom of the container and catch the water that drains out.

12. The volume of drainage water equals the Air Space or Air Volume since air moves into the media as the water drains away.

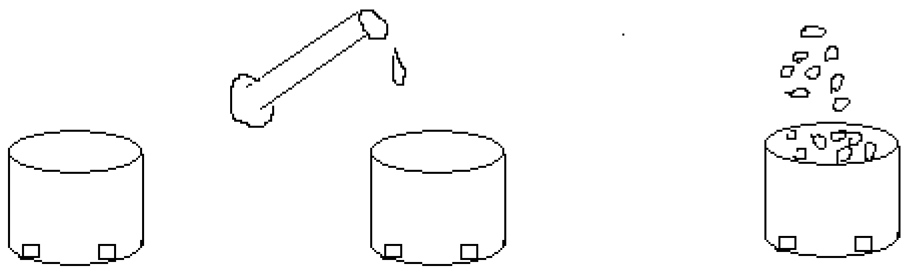
13. Subtract the drained water from the total water added. This gives the water retained in the mix or is the Water Space or Water Volume.

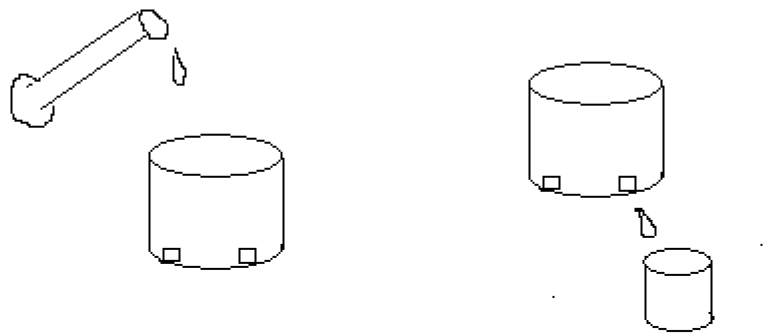
14. All readings are on a volume basis and in (ml).

Tape Holes

Determine **TOTAL VOLUME** volume (ml)
(Example: **5000 ml**)

Drain and fill with media, compress slightly





Add water slowly to media surface. This volume equals **Total Porosity**
(Example: **3000**)

Drain water = **Air Volume**
(Example: **1000 ml**)

Total Porosity minus **Air Volume = Water Volume**
(Example: **2000 ml**)

Develop all values into percentages (%).

$$\mathbf{\frac{3000}{5000} \times 100 = 60\%}$$ **Total Volume**

$$\mathbf{\frac{1000}{5000} \times 100 = 20\%}$$ **Air Volume**

Total Porosity – Air Volume = Water Volume

60% - 20% = 40%

SUGGESTED VALUS: AIR SPACE = 20-30%
WATER SPACE = 30% +

INFORMATION FROM “HORTICULTURAL AND AGRICULTURAL USES OF SAWDUST AND SOIL AMMENDMENTS, TECHNICAL BULLETIN 1968, PAUL JOHNSON

PHYSICAL PROPERTIES OF AMENDMENTS, SOILS AND MIXTURES.

TEST MATERIAL	WATER RETENTION CAPACITIES		AIR RELATIONSHIPS (VOLUME PERCENT)		
100%	Volume Percent	Total Porosity	Air Space After Drainage	(1/8 “ = 3 mm) (1/4” = 6 mm) (½” = 12 mm)	(3/16” = 5 mm) (3/8” = 9 cm) (5/8” = 16 mm)
Bark, fir 0-1/8”	38	69.5	31.5		
Bark, fir 1/8-5/8”	15	69.7	54.7		
Bark, redwood 3/8”	30.8	80.3	49.5		
Loam, clay	54.9	59.6	4.7		
Loam, sandy	35.7	37.5	1.8		
Peat, sedge, AP	52.3	69.3	17		
Peat, sedge, BD	68.6	77	8.4		
Peat, sedge BP	47.6	68.1	20.5		
Peat, sedge MP	53.7	73.5	19.8		
Peat moss, hypnum	59.3	71.7	12.4		
Peat moss, sphagnum	58.8	84.2	25.4		
Perlite, 1/50 - 1/16”	42.6	75.8	33.2		
Perlite, 1/16 - 3/16”	47.3	77.1	29.8		
Perlite, 3/16 - ¼”	19.0	75.3	56.3		
Perlite, ¼ - 5/16”	19.5	73.6	53.9		
Pumice, 1/50 - 1/16”	40.5	62.2	21.7		
Pumice, 1/16 - 1/8”	33.0	65.2	32.2		

Pumice, 1/8 - 5/16”	25.9	60.3	34.4
Pumice, 5/16 - 5/8”	25.5	70.5	45.0
Rice hulls	12.3	81.0	68.7
Sand, builders	26.6	36.0	9.4
Sand, fine A	33.7	36.2	2.5
Sand, fine, B	38.7	44.6	5.9
Sawdust, cedar	38.2	80.8	42.6
Sawdust, redwood	49.3	77.2	27.9
Vermiculite, 0 - 3/16”	53.0	80.5	27.5
Manure, dairy	66.7	74.3	7.6

50/50 (volume/volume) Mixtures using:

Clay loam with the following materials:

Peat, sedge	56.5	61.8	5.3
Peat moss, hypnum	59.9	66.2	6.3
Peat moss, sphagnum	61.0	71.0	10.0
Sand, builders	40.8	47.0	6.2
Sand, fine	41.5	47.4	6.9
Sawdust, redwood	57.6	72.0	14.4

Sandy loam with the following materials:

Peat moss, hypnum	49.8	54.2	4.4
Peat moss, sphagnum	52.8	59.1	6.3
Sawdust, redwood	52.7	62.8	10.1

Fine sand with the following materials:

Bark, fir, 0 - 1/8”	37.4	54.6	15.2
Bark, fir, 1/8 - 5/8”	36.0	44.3	8.3
Bark, redwood 3/8”	43.5	56.8	13.3
Peat moss, hypnum	49	55.5	6.5
Peat moss, sphag.	47.3	56.7	9.4
Perlite, 1/16 - 3/16”	42.6	52.0	7.6
Perlite, 3/16 - ¼”	38.5	43.2	4.7
Perlite, ¼ - 5/16	34.6	41.5	6.9
Pumice, 1/16 - 1/8”	37.5	42.3	4.8

Pumice, 1/8 - 5/16”	33.5	37.3	3.8
Pumice 5/16 - 5/8”	35.2	37.3	2.1
Sawdust, redwood	40.5	52.6	12.1

Peat moss with the following material:

Perlite, 3/16 - ¼”	51.3	74.9	23.6

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INFORMATION FROM “HORTICULTURAL AND AGRICULTURAL USES OF SAWDUST AND SOIL AMMENDMENTS, TECHNICAL BULLETIN 1968, PAUL JOHNSON

PHYSICAL PROPERTIES OF AMENDMENTS, SOILS AND MIXTURES.

TEST MATERIAL	WATER RETENTION CAPACITIES	AIR RELATIONSHIPS (VOLUME PERCENT)	
100%	Volume Percent	Total Porosity	Air Space After Drainage
Peat moss, sphagnum	58.8	84.2	25.4
Rice hulls	12.3	81.0	68.7
Sand, builders	26.6	36.0	9.4
Sand, fine A	33.7	36.2	2.5
Sand, fine, B	38.7	44.6	5.9
Sawdust, cedar	38.2	80.8	42.6
Sawdust, redwood	49.3	77.2	27.9
Manure, dairy	66.7	74.3	7.6

50/50 (volume/volume) Mixtures using:

Clay loam with the following materials:			
Peat moss, sphagnum	61.0	71.0	10.0
Sand, builders	40.8	47.0	6.2
Sand, fine	41.5	47.4	6.9
Sawdust, redwood	57.6	72.0	14.4
Fine sand with the following materials:			
Peat moss, sphag.	47.3	56.7	9.4
Perlite, 1/16 - 3/16”	42.6	52.0	7.6
Sawdust, redwood	40.5	52.6	12.1
Peat moss with the following material:			
Perlite, 3/16 - ¼”	51.3	74.9	23.6

APPENDIX: 19

SOIL PARTICLE SIZE AND CONSTITUENTS

GENERAL: Soil plays two major roles; one is to hold the plant in an upright position and second, it acts as a bank to hold nutrients, oxygen and water. Needless to say, it also contains many other items…some useful and others that may cause problems: i.e. bacteria, fungi, viruses and a number of other non-essential products.

BASIC SOIL INGREDIENTS: Organic materials, sand, silt and clay. Each of these materials plays a role in crop growth. Their influence is related both to their physical size and chemistry. The ingredient with the smallest size usually has the greatest effect on the total media. For the scientists among us, the following are used to identify these particles.

a. Organic materials: made primarily of carbon, oxygen and hydrogen. As they decompose (rot) many electrical charged sites develop on their surfaces…primarily negatively charged like the negative end of a magnet (-).

b. Sand: 1.0-0.05 mm
   Particles in 1 gram of fine sand = 46,213
   Total surface area of one gram = 90.7 sq.cm.
   The mineral base can be of almost anything.
   Feels gritty to the touch.
   Essentially no electrically charged sites.

c. Silt: 0.05-0.002 mm
   Particles in 1 gram = 5,776,674
   Total surface area of one gram = 453.7 sq.cm.
   Mineral base
   Feels "slippery" to the touch without being "sticky"
   Few electrically charged sites….(negative (-).

d. Clay: 0.002-0.0002mm, 0,0002 and small – colloidal clay = gluelike
   Particles in 1 gram = 90,260,853,860
   Total surface area of one gram = 11,342 sq.cm. (12 sq.ft.)
   Mineral base
   Feels "sticky" to the touch, almost like glue.
   Contains many electrically charged sites….negative (-).

A typical soil is a combination of all of the above. Likewise, because some soils have more of one ingredient that another, they are classified by different names. In short, some soils produce good crops and others, very poor crops. Other than the crop's nutrient needs, there is a great need for oxygen since these are living organisms like us.

When a soil is watered, each soil particle becomes surrounded by a microscopic film of water. If the soil particles are extremely small, there is essentially no space left for air (oxygen) and plant growth is very poor. On the other hand, if the soil particles are very large, (gravel), the crop must be watered several times each day to prevent wilting and death. This latter method is used to a great advantage in hydroponic production.

ROOTS NEED OXYGEN: any part of a plant that is growing rapidly needs a great deal of oxygen. One of the roles of the expert gardener is to evaluate their soil and its ability to supply oxygen. The gardener can always add nutrients and water but it is near impossible to “add” oxygen. Forget the peroxide pills!!!

SOIL NUTRIENTS: Let’s look next at the ability of a soil to supply nutrients. Remember, one of the tasks of a soil is that it acts like a nutrient bank.

Nutrients come in many forms, manure, green leaves and elemental fertilizers in either a dry or liquid form. In all cases, the nutrient as it is taken in by the plant is usually in a very simple elemental complex, such as nitrate, ammonium, potassium, iron, calcium etc. When elemental fertilizers are dissolved in water, they come apart into two pieces. One piece carries a (+) charge and the other a (-) charge…again, just like magnets. Remember that some soils have lots of (-) charge sites….those with lots of clay and organic matter. These will hold the (+) fertilizers and will trade them for hydrogen (+) which is given off by the plant root. In short, the soil’s ability to “trade” nutrients for hydrogen is referred to as Cation Exchange Capacity or CEC. A “cation” is a positively charge element and the negatively charged elements are called “anions”.

Evaluate soils: water bottle test…how much sand, silt, clay and organic matter?

- Canby Sand: sand settles out in only a few seconds
- Silt Loam: silt settles out usually in an hour at the most
- Clay: a clay layer may not be seen for 24 hours and much will remain suspended in the water.

Compare the thickness of each layer as a percentage of the total.

- Soils high in clay usually contain little air space. The clay particle is usually in layers and water and nutrients can be held between the layers. Cracking often occurs as the soil dries due to the shrinkage of these layers.
- Soils high in silt usually hold only a small amount of water and are very prone to cracking as they dry out…root breakage.
- Soils high in sand hold very little water and can also hold very little air immediately following an irrigation particularly if the sand particles are round and small. (Columbia River sand…often sold locally as “top soil”…don’t buy it!!).
- Soils high in organic matter are often black in color, hold lots of nutrients and water but also are very prone to shrinkage with time… Organic matter decomposes to carbon dioxide and water. Highly organic soils are often referred to as “muck soils” such as in Lake Labish just north of Salem. As the organic materials decompose, the surface level of the field slowly recedes.

HOW TO IMPROVE MOST SOILS - ADDITION OF ORGANIC MATERIALS:

- Peat Moss, Manures, Decayed Leaves, Green Leaves: The addition of almost any kind of organic matter will improve oxygen levels because of the coarse texture of the materials. Keep in mind that different kinds of organic matter decompose at different rates. Peat decomposes very fast, bark is extremely slow. Similarly, nutrient levels are totally dependent on the type of organic material used…manure vs. bark dust.
- Poultry Manures: Excessively fine organic matter (poultry manure) should be added in small amounts because it can reduce the oxygen content. Poultry manure also contains a great deal of soluble nutrients. If too much is added at one time, fertilizer burn will occur. Apply no more than 1 inch if it is to be tilled into the soil. A half an inch is sufficient if it is to be left on the surface.
- Cattle and Horse Manure: Fresh or nearly fresh cow and horse manures and leaves are all good. Use probably no more than 2 inches on the soil surface and then work it into the soil. Older or aged materials can be used in larger amounts.
- Bark and Sawdust: The use of sawdust or bark often causes nutrient deficiency problems. Soil bacteria and fungi need lots of nitrogen in their diet to attack woody materials such as old dry leaves, sawdust and bark dust. If these materials are added to your soil without adding extra nitrogen, crops will suffer. In short, bacteria and fungi are much more efficient at taking nitrogen out of the ground than the plant. Nitrogen depletion when using bark or sawdust (mixed into the soil): Add 2-3 cups of ammonium nitrate or ammonium sulfate per 10 x 10 foot area (3 x 3 meters) for each one inch of sawdust/bark dust added prior to working the soil. Watch the plants color. A light green plant usually indicates low nitrogen levels in the soil. When bark or sawdust is used as mulch on the soil surface, addition of extra nitrogen is generally not needed.

OXYGEN in the key…roots need lots…anything you can do to increase water drainage and air movement into and out of the soil will promote better growth. HOWEVER, SAND AND CLAY MAKES SUPER CONCRETE….DON'T ADD SAND TO SOIL…USE ORGANIC MATTER OF SOME TYPE.